



AFRL-RX-WP-TM-2009-4203

POLYMERIC MATERIALS

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Nonmetallic Materials Division**

**JUNE 2009
Final Report**

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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YY) June 2009		2. REPORT TYPE Final		3. DATES COVERED (From - To) 01 October 2002 – 01 June 2009	
4. TITLE AND SUBTITLE POLYMERIC MATERIALS				5a. CONTRACT NUMBER In-house	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 62102F	
6. AUTHOR(S) Richard A. Vaia				5d. PROJECT NUMBER 4347	
				5e. TASK NUMBER RG	
				5f. WORK UNIT NUMBER M01R1000	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Polymers Branch (AFRL/RXBN) Nonmetallic Materials Division Air Force Research Laboratory, Materials and Manufacturing Directorate Wright-Patterson Air Force Base, OH 45433-7750 Air Force Materiel Command, United States Air Force				8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-RX-WP-TM-2009-4203	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory Materials and Manufacturing Directorate Wright-Patterson Air Force Base, OH 45433-7750 Air Force Materiel Command United States Air Force				10. SPONSORING/MONITORING AGENCY ACRONYM(S) AFRL/RXBN	
				11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S) AFRL-RX-WP-TM-2009-4203	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES PAO Case Number: 88ABW-2010-1593; Clearance Date: 25 March 2010.					
14. ABSTRACT This report summarizes the technical progress of the in-house projects supporting the Polymeric Materials Effort, Materials and Manufacturing Directorate, Air Force Research Laboratory. These include structurally and morphologically tailored materials for improved photovoltaic and molecular electronic responses; bio-derived photonic assemblies; advanced polymeric materials; polymer nanostructured materials; and polymer nanostructured materials (PNMs).					
15. SUBJECT TERMS Polymer, Nanomaterials, Structure					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT: SAR	18. NUMBER OF PAGES 46	19a. NAME OF RESPONSIBLE PERSON (Monitor) Richard A. Vaia 19b. TELEPHONE NUMBER (Include Area Code) N/A
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			

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1.0 Structurally and Morphologically Tailored Materials for Improved Photovoltaic and Molecular Electronic Responses

1.1 Research Objectives:

1. Model electron-sponges, materials capable of multiple reversible electrochemical reductions, at theoretical levels adequate to treat the complex electron-electron and electron-lattice interactions intrinsic to such redox processes.
2. Prepare and characterize electronic-accepting molecules and n-dopable polymers based on thiazolothiazole and thieno[3,4-b]thiophene materials expected to have good electron-accepting properties and enhanced charge mobilities.
3. Evaluate materials and structures for improved charge transport characteristics within photovoltaic devices.
4. Evaluate novel processing techniques for control of the nanoscale architecture of thin films for photovoltaic device applications.

1.2 Summary of Progress:

FY04 saw a number of important developments in meeting all four objectives. The level of theory required to accurately map geometric distortions in fullerenes was better defined. This enables the electronic-lattice coupling to be modeled, which is of central importance in electron transfer processes. Advances in the synthesis of thiazolo[5,4-b]thiazoles paved the way for developing monomers with good polymer-forming reactions. The electron-accepting capability of thiazolo[5,4-b]thiazoles was modeled by high level calculations and found to exceed that of C60 even for a short (i.e. pentamer) oligomer. Photovoltaic cells were fabricated and evaluated using thienylvinylene polymers with bulk heterojunction cells. Nanotubules of TiO₂ were grown via templating within nanoporous Al₂O₃ films. For FY04 there were refereed publications, unrefereed publications, patents, book chapters, and presentations (of which seven were invited).

Progress was made for all four objectives in FY05. The electron attachment energy for the C₁₂₂ dianion was found to be significantly endothermic which is counter intuitive. Modeling reorganization energies of electron-accepting materials has led to a number of promising structures for enhanced mobility. Novel PBZT-thienylthiophene polymers were prepared and characterized for enhanced spectral response. Previously developed quaternization chemistry was applied to BBL and BBB materials with surprising solubility. Thermal history was found to be significant in determining performance of devices made with alternative conjugated polymers. By optimizing thermal conditioning and combining these new conjugated polymer systems with current state of the art (SOA) devices, the next step is to fabricate 'multi-junction' devices to harvest energy in multiple solar spectral regions. Two new, alternative processing techniques were examined for fabrication and interfacial modification of active devices. Initial efforts demonstrated the utility of holographic photopolymerization for patterning electronically active materials. A proof of concept demonstration will be pursued to show its use in the fabrication of PVs. Layer-by-layer assembly was utilized to deposit ultra-thin, interfacial modification layers of the

conducting polymer, PEDOT, which is routinely used as the buffer layer in PVs, and of the gate dielectric in organic thin film transistors. Further work will involve demonstrating this technique for transistors based on small molecules, such as pentacene. For FY05 there were refereed publications, unrefereed publication, patent, book chapters, and presentations (invited).

2.0 Bio-Derived Photonic Assemblies

2.1 Research Objectives:

The goal of this task is to develop techniques to manipulate naturally occurring periodic materials into mechanically robust, photonic crystal systems possessing 3D band structures that cannot be obtained through traditional methods. Two general approaches will be examined: 1) top-down fabrication based on size reduction of micron-scale periodic structures, such as found in sea urchin skeletons, and 2) bottoms-up fabrication based on assembly of viral particles such as the iridiovirus. In addition, the investigated processing and fabrication techniques will be integrated with conventional microfabrication technologies to optimize potential for integrated optic devices.

2.3 Summary of Progress:

Photonic band gap structures provide enticing platforms to combine large-scale processability (classical motivation driving polymer use) with enhanced photonic properties via exploitation of spatially-defined and locally enhanced optical fields. Current studies have barely scratched the surface of the multitude of possible structures and material properties that might be exploited, but have been limited by the complexity associated with fabrication of these more complex structures. Naturally occurring biomaterials can be used as scaffolds to construct photonic crystals with structures that are difficult/impossible to fabricate by artificial means. Two general areas are being explored within this program: biotemplates and biocolloids, essentially being top-down and bottom-up approaches to photonic crystals. With regard to biotemplates, simulations predict a complete 3D bandgap, given sufficient dielectric contrast (9:1), for the sea urchin *cidaris cidaris* skeleton ("Plumber's Nightmare" surface (space group Pm3m), 50 micron lattice. A novel cyclic size-reduction scheme enabled reduction and replication of the structure by approximately 50% per cycle allowing a tailorable photonic crystal structure in the IR-spectral region. With regard to biocolloids, forced assembly of iridiovirus (200 nm) using ultra-centrifugation and a glutaraldehyde cross-link scheme provided colloidal crystals with reflectivities that depend on pellet thickness and water content. Development of surface patterning techniques to enable directed assembly of the biocolloids have lead to the development of a new AFM-patterning technique based on local resistive heating of polymer film above its glass transition and subsequent electrostatic attraction toward the tip. Since polymer is not degraded in the process, the patterns are reworkable through application of an external thermal field. The program is jointly executed with Prof. Edwin Thomas at MIT. In addition, the program leverages an AOARD grant to Prof. Vernon Ward, Department of Microbiology, and University of Otago, New Zealand.

3.0 Advanced Polymeric Materials

3.1 Research Objectives:

The goal of this task is to provide the fundamental knowledge base to develop high performance polymers for diverse Air Force applications. The research effort focuses on two primary objectives: (1) Unusually high performance and environmental properties in polymeric materials for Air Force structural applications; (2) Desirable photonic properties in organic and polymeric materials having environmental resistance, structural performance, or multi-functional capability.

3.2 Summary of Progress:

FY02 research activities have covered the area of high performance structural polymers (rigid-rod polymers with improved compressive strength, functionalized single-wall carbon nanotubes and hyperbranched polymers) and organic two-photon materials (optical limiting applications and microfabrication). Among several new aromatic and heterocyclic-aromatic hyperbranched polymers prepared, an allyl-terminated hyperbranched poly(ether-ketone-imide) was found to be very effective in reducing the melt viscosity (65x less) when blended with a BMI resin at 4 wt%. Initial mechanical testing results indicated 80-100% improvement in toughness with a two-fold increase in modulus. Also, linear-hyperbranched random copolymerization was found to be effective in suppressing the crystallinity of semicrystalline linear polyetherketone. Unusual solution viscosity behaviors were also noted for a number of hyperbranched benzoxazole-quinoxaline polymers. Research on third-order nonlinear optical materials continues to focus on improving AFX-based two-photon resonant (TPA) materials for the optical power limiting applications and microfabrication. In addition, efforts have been initiated to explore research and application opportunities in nanophotonics and biophotonics in conjunction with an AFOSR-DURINT program on the same theme. During FY02, journal articles (refereed), presentations, and patent actions with task personnel as authors were recorded.

FY03 research activities have covered the areas of high performance structural polymers (block copolymers based on rigid-rod polymers, functionalized carbon nanofiber (CNF) and hyperbranched polymers) and organic two-photon materials (optical limiting applications and microfabrication). The ABA triblock copolymers were prepared from the copolymerization of carboxylic acid-terminated PBZT and an appropriate AB₂ monomer to generate the hyperbranched poly(ether-ketone) A-blocks in polyphosphoric acid. The resulted ABA triblock copolymer with phenoxy-terminated hyperbranched A-blocks were soluble in NMP and that with carboxylic acid end-groups was soluble in alkaline aqueous solution, thus providing the spectroscopic properties of rigid-rod PBZT in non-protonated state in solution for the first time. A new method was developed to covalently attach arylcarbonyl groups (3 in every 100 carbons of the CNF). Preliminary results also indicated that the grafting of a poly(ether-ketone) onto the surfaces of CNF is possible, thus opening the door to a variety of designed blends and composite materials. Research on third-order nonlinear optical materials continues to focus on improving AFX-based two-photon

resonant (TPA) materials for the optical power limiting applications, microfabrication, and novel energy-transfer systems. Specifically, AF-455 has been identified as a very promising material for sensor protection as evaluated by MLPJ. During FY03, 27 journal articles (12 refereed), 17 presentations (6 invited), and 14 patent actions with task personnel as authors were recorded.

FY04 research activities have covered the areas of high performance structural polymers, *viz.* chain-end-functionalized hyperbranched polymers (PAEKI), and *in-situ* nanocomposites based on vapor-grown carbon nanofibers (VGCNF) as well as organic two-photon materials (optical limiting applications and microfabrication). The hyperbranched PAEKI were functionalized with reactive end-groups such as phthalonitrile (PN), ethynyl (ET) and phenylethynyl (PE) that are chemically compatible with the respective high-temperature thermoset resins. PE-PAEKI is being evaluated at MLBC for applicability in the polymer matrix composite program as a high-temperature processing additive for AFR-PE-RTM resins. From the standpoint of affordability, an “A₂+ B₃” synthetic methodology was explored with commercially available A₂-monomers and B₃ cross-linkers. An *in-situ* nanocomposite was successfully generated from the grafting of a *meta*-poly(ether-ketone) onto VGCNF via a Friedel-Crafts acylation in poly(phosphoric acid) with up to 30 wt% VGCNF. Research on third-order nonlinear optical materials continues to focus on improving AFX-based two-photon resonant (TPA) materials for AF needs in sensor protection area with the new emphasis on enhanced excited state absorption and emission quenching under laser irradiation. In addition, some efforts are also directed toward incorporating AFX into optically clear polymer matrices that can lend themselves easily to fibers or windows. Finally, large-scale coarse-grained molecular dynamics simulations of nanomaterials are currently ongoing to better understand what inherent properties are most important to the development of well dispersed nanoparticles. During FY04, publications (refereed), presentations (invited), and patent actions with task personnel as authors were recorded.

FY05 research activities have covered the areas of high performance structural polymers, *viz.* chain-end-functionalized hyperbranched polymers (PAEKI), and *in-situ* nanocomposites based on vapor-grown carbon nanofibers (VGCNF) as well as organic two-photon materials (optical limiting applications and microfabrication). The hyperbranched PAEKI were functionalized with phenylethynyl (PE) group with ortho-, para- and meta-substitution pattern. The thermal analysis results indicated the para-PE has wider processing window than the other two systems. 50 g scale-up synthesis of para-PE-PAEKI was also successful. It is being evaluated at MLBC for applicability in the polymer matrix composite program as a high-temperature processing additive for AFR-PE-RTM resins. Further demonstration of functionalization of VGCNF with the Friedel-Crafts/PPA method developed previously was successful to provide surface-modified VGCNF with an aromatic amine function. *In-situ* polymerization of 6FDA and an aromatic diamine in the presence of amine-grafted VGCNF has afforded the corresponding polyimide composite films with VGCNF content ranging from 0.1-5 wt%. Research on third-order nonlinear optical materials continues to focus on improving AFX-based two-photon resonant (TPA) materials for AF needs in sensor protection area with the new emphasis on enhanced excited state absorption and emission

quenching under laser irradiation. In addition, some efforts are also directed toward incorporating AFX into optically clear polymer matrices that can lend themselves easily to fibers or windows. The possibility of extending the application of TPA materials to CCD camera protection is being examined together with RXPJ. Finally, a molecular dynamics simulation study incorporating the effect of solvent and temperature on the conformation and dynamics of the nanoclay sheets was completed. The result suggests their swelling on reducing the temperature in a poor solvent, based on the preliminary analysis of the equilibrium radius of gyration of the sheet. During FY05, publications (refereed), presentations (invited), and patent actions with task personnel as authors were recorded.

FY06 research activities have covered the areas of high performance structural polymers, *viz.* thermally cross-linkable hyperbranched polymers (PAEKI) functional additive for high temperature thermosets, and *in-situ* nanocomposites based carbon nanofibers and nanotubes as well as two-photon materials (sensor protection and microfabrication). Improvement in the synthesis of the hyperbranched PAEKI functionalized with para-phenylethynyl (PE) has reduced the number of steps from 5 to 3; greatly facilitate the materials availability for further processing optimization studies and fabrication of carbon-fiber composite panels based on AFR-PE-RTM. At 3 additive wt%, PE-PAEKI was able to stabilize the melt viscosity of an AFR-PE-RTM resin at isothermal condition (280 °C). Further demonstration of functionalization of VGCNF with the Friedel-Crafts/PPA method developed previously was successful to provide surface-modified VGCNF with hyperbranched poly(ether-ketone), which drastically improved the solubility/dispersibility of the resulting nanocomposites in common organic and aqueous solvents. Promising extension of this synthetic methodology to MWNT & SWNT is currently underway. Research on third-order nonlinear optical materials continues to focus on improving AFX-based two-photon resonant (TPA) materials for AF needs in sensor protection area with the new emphasis on enhanced excited state absorption and emission quenching under laser irradiation. In addition, some efforts are also directed toward incorporating AFX into optically clear polymer matrices that can lend themselves easily to fibers or windows. The possibility of extending the application of TPA materials to CCD camera protection and space sensor protection is being examined together with MLPJ. During FY06, publications (refereed), presentations (invited), and patent actions with task personnel as authors were recorded.

4.0 Polymer Nanostructured Materials (PNMs)

4.1 Research Objectives:

The Goal of this task is to provide the knowledge base to *develop* and *evaluate* polymer-based nanostructured materials for diverse Air Force applications that require multi-functionality and/or responsivity from the material system. New properties derived from nanoscopic dimensions enable the creation of such materials and the circumvention of classic property-processing trade-offs. The laboratory task focuses on two primary objectives: (1) Creating the fundamental understanding necessary to establish predictable structure-processing-property (SPP) relationships for polymers containing nanoparticle dispersions and (2) demonstrating the feasibility of these polymer nanocomposites to address unique military needs. The establishment of SPP relationships is enabled by innovations ranging from morphological techniques that quantitatively identify a “critical volume element representative of the bulk characteristics,” to novel synthetic methodologies to create nanoparticle assemblies that exhibit liquid-characteristics at room temperature. These fundamental investigations provide the basis to evaluate polymer nanocomposites (PNCs) for Air Force needs including RF/Microwave systems (antennas, negative index materials, RF MEMs switches), “morphing” aero-structures, and self-sensing / self-responsive structures.

4.2 Summary of Progress:

Polymer-based nanostructured materials (PNMs) provide many opportunities to address current technological shortfalls, as well as providing for future military systems. New properties derived from nanoscopic dimensions enable the creation of multi-functional materials, which circumvent classic property-processing trade-offs. To establish feasibility for military needs, current opportunities being examined include:

1. Electrically conductive elastomers for electromagnetic management and shielding,
2. Active materials (stress recovery and dynamic stiffness) for deployables and morphing aerostructures,
3. Piezo- and pyro-resistive PNM for health monitoring via strain and temperature sensing.
4. Magnetic nanoparticle/polymer nanocomposites for microwave/RF applications,
5. High-temperature thermoset resins,
6. Photonic band gap materials with tailorable susceptibility for light amplification (lasing), optical limiting and nonlinear-optics, and
7. Polymer nanofabrication approaches for device and data storage concepts on flexible substrates.

To enable complete evaluation of the potential of PMNs, pervasive fundamental issues common to these opportunities are addressed, and when required unique modeling and experimental approaches, such as NMR, scattering or nano-probe techniques are developed.

Example efforts during FY03 with noteworthy findings include: 1) emulsion-based PNM synthesis routes, 2) template synthesis of carbon nanotubes with prescribed length and diameter, 3) models, theory and supporting experiment to quantify morphological features of PNMs by x-ray scattering, 4) establishment of NMR facility and application to organic-inorganic interfacial behavior, 5) quantification of nanoparticle response to external fields, such as electrical and shear, 6) utilization of holographic photopolymerization to create switchable organic lasers and 7) detailed development of structure-deformation-property models for remotely actuated stress recovery of nanotube-elastomer nanocomposites. During FY03, journal articles (refereed), presentations (invited), and patent action with task personnel as authors were recorded.

Example efforts during FY04 with noteworthy findings include: 1) development of initial magnetic nanoparticle nanocomposites for RF/microwave evaluation, 2) adhesive approach for creating multicomponent interposed carbon nanotube micro-patterns by region-specific contact transfer and self-assembling on soft-matrices, 3) development of a spin-on-catalyst system for single-wall carbon nanotubes models, 4) demonstration of single-step fabrication of electrically switchable, optically pumped lasing in an organic PBG, 5) impact of deformation on polymer crystallinity within semicrystalline polymer nanocomposites, and 6) detailed development of structure-deformation correlation for conductive nanotube-elastomer nanocomposites. During FY04, 31 journal articles (24 refereed), 47 presentations (18 invited), and 3 patent actions with task personnel as authors were recorded. During FY05, funding for NMR of Inorganic-Organic Interfaces will be transferred to other sources and emphasis will be on the elucidation of structure-property correlations (and the necessary approaches) to facilitate development of mechanically adaptive (actuators), optically adaptive (optically limiting PBGs) and RF/microwave systems.

Example efforts during FY05 with noteworthy findings include: 1) demonstration of tri-axial control of nanoparticle orientation distribution through a uniaxial external processing field (magnetic); 2) development of models to predict electric field impact on alignment, exfoliation and buckling of nanoplates in electric fields; 3) development of HREM techniques for lattice imaging, defect evaluation and observation of local failure modes of layered silicates; 4) demonstration of single-step fabrication of all organic two-dimensional, PBGs with electrically tunable, optically pumped lasing; and 5) synthesis of complex core-shell hard-soft magnetic nanoparticles exhibiting spin coupling. During FY05, 46 journal articles (23 refereed/submitted) and 73 presentations (32 invited) with task personnel as authors were recorded. Additionally, task personnel were interviewed by Popular Mechanics, Aviation Week, High Performance Composites and C&E News. Also, the current task has enabled the successful leveraging of additional external funding from the CIA and ONR as well as the continual growth of complementary computer simulations (PI: Barry Farmer). To enable future growth, developments on soft-matter patterning have been concluded. During FY06, optically adaptive materials for optical limiting applications will be phased-out of this task and solely supported by 96ML03COR (PI: L-S Tan) and AFRL/MLPJ. Emphasis will continue on the elucidation of structure-property correlations

(and the necessary approaches) to facilitate development of optically-triggered, mechanically adaptive and RF/microwave systems as well as to begin to explore molecular and nano-based approaches to tailoring interface adaptivity and to tailor ϵ and μ (e.g. negative n materials).

Example efforts during FY06 with noteworthy findings include: 1) demonstration of utility of cryogenic compounding to enhance dispersion of nanoparticles in B-staged epoxy resins; 2) calculation of the magnitude and decay length of the interaction potential between two sheets of montmorillonite; 3) development of processing techniques to create optically active viral assemblies (highlighted on cover of Advanced Functional Materials); 4) extension of durability of RF MEMs switching by 1 order of magnitude using Au nanoparticle liquids and 5) completion of scale-up 13g of Fe₃O₄ core for preparation of a 5 inch x 5 inch x 40 mil antenna substrate based on Irogran containing a Fe₃O₄/CoFe₂O₄ core/shell nanoparticle. During FY06, 22 journal articles (17 refereed/submitted), 2 patent applications and 49 presentations (25 invited) with task personnel as authors were recorded. Additionally, Dr. Vaia spent 6 months at UCSB Materials Research Laboratory developing concepts for polymer nanocomposite dielectrics, predicting and quantifying nanoparticle-polymer phase behavior, and surface chemistries for interfacial adaptivity. To complement these efforts, collaborative programs with external funding have been established, including membership at the BNLS X27C Beam Line, two visiting ASEE Summer faculty, two EOARD programs, two CINT (Sandia)-funded programs and two approved proposals for neutron scattering time at NIST. To enable future growth, optically adaptive materials for optical limiting applications was phased-out of this task and solely supported by 96ML03COR (PI: L-S Tan) and AFRL/MLPJ. Emphasis will continue on the elucidation of structure-property correlations (and the necessary approaches) to facilitate development of remotely-triggered, mechanically adaptive and RF/microwave systems as well as to begin to explore molecular and nano-based approaches to tailoring interface adaptivity, to tailor ϵ and μ (e.g. negative n materials) and to explore possibilities for polymer nanocomposites dielectrics.

Example efforts during FY07 with noteworthy findings include: 1) determination that electric fields can enhance nanoparticle dispersion (exfoliation) process; 2) development of electron tomography techniques to quantitatively evaluate nanoparticle dispersion in three-dimensions; 3) robust synthesis protocol for controlled purity nanoparticle liquids and subsequent further extension of durability of RF MEMs switching to 3 orders of magnitude over current Au coated SOA surfaces; 4) demonstration of hybrid shape memory foam concept to enable separation of energy storage and shape recovery processes, and 5) fabrication of monodisperse MFe₂O₄ (M= Mn, Y, Co) and Fe₃O₄ spherical nanoparticles, as well as SmFe₂O₄ nanocubes via thermal decomposition and seed-mediated growth methods. To complement these efforts, collaborative programs with external funding have been established, including membership at the BNLS X27C Beam Line, one visiting ASEE Summer faculty, one EOARD program, two CINT (Sandia)-funded programs and six approved proposals from AFRL/ML's FY07 Laboratory Directors Funds. During FY07, 11 journal articles, 5 patent actions and 72 presentations (33 invited) with task personnel as

authors were recorded. FY07 was the last year for this task. The fundamental investigations from this task has provided numerous opportunities for AF development programs (e.g. Shape Memory Polymer Nanocomposites for Morphing Aircraft) as well as revolutionary directions for future fundamental projects focused on single-phase, structured nanoparticle assemblies (e.g. Nanoparticle Liquids, NanoDielectrics, Large Verdet Materials).

5.0 Publications (Refereed):

2001

Fong, H.; Vaia, R.A.; Sanders, J.H.; Lincoln, D.; Vreugdenhil, A.J.; Liu, W.; "Self-Passivation of Polymer-Layered Silicate Nanocomposites." *Chemistry of Materials* (2001), 13(11), 4123-4129.

B. Sankaran, M. D. Alexander, Jr. and L.-S. Tan, "Synthesis, Emission and Spectro-electrochemical Studies of Bithienylnaphthalene Systems," *Synthetic Metals*, 123, 425 (2001).

Y. Shen, J. Swiatkiewicz, P. N. Prasad, and R. A. Vaia, "Hybrid Near-Field Optical Memory and Photofabrication in Dye-doped Polymer Film," *Opt. Commun.*, 200, 9-13 (2001).

Shen, Y.; Swiatkiewicz, J.; Prasad, P. N.; Vaia, R. A.. Hybrid near-field optical memory and photofabrication in dye-doped polymer film. *Optics Communications* (2001), 200(1-6), 9-13.

L.-S. Tan, S. Smko, S. J. Bai, R. A. Vaia, B. E. Taylor, M. D. Houtz, M. D. Alexander, Jr. and R. J. Spry, "Phase-Separated, Conducting Composites from Polyaniline and Benzobisthiazole Rigid-Rod Polymer," *J Polym. Sci. Part B: Polym. Phys.* 39, 2539 (2001).

Tan, L.-S.; Smko, S.R.; Bai, S.J.; Vaia, R.A.; Taylor, B.E.; Houtz, M.D.; Alexander, M.D., Jr.; Spry, R.J., "Phase-separated, conducting composites from polyaniline and benzobisthiazole rigid-rod polymer" *Journal of Polymer Science, Part B: Polymer Physics* (2001), 39(20), 2539-2548.

Vaia, R. A.; Dennis, C. L.; Natarajan, L.V.; Tondiglia, V. P.; Tomlin, D.W.; Bunning, T. J. "One-step, micrometer-scale organization of nano- and mesoparticles using holographic photopolymerization: a generic technique." *Advanced Materials* (2001), 13(20), 1570-1574.

2002

J.-B. Baek, H. Qin, P. T. Mather and L.-S. Tan "A New Hyperbranched Poly(arylene-ether-ketone-imide): Synthesis, Chain-End Functionalization, and Blending with a Bis(maleimide)" *Macromolecules*, 35, 4951, (2002)

M. Banach, S. Clarson, G. Beaucage, J. Benkoski, T. Mates, E. Kramer, R. Vaia, "Fabrication and Characterization of Planar and Channel Polymer Waveguides. III. Compositional Distribution and solute loss in Polymer Thin Films," *J Appl. Polymer Science*, 86, 2021 (2002).

Bharadwaj, R. K.; Vaia, R. A.; Farmer, B. L. "A coarse-grained simulation study of polymer melt intercalation in layered nanostructures." ACS Symposium Series (2002), 804(Polymer Nanocomposites), 209-223.

L. Y. Chiang, P. A. Padmawar, T. Canteenwala, L.-S. Tan, G. S. He, R. Kannan, R.A. Vaia, T.-C. Lin, Q. Zheng, and P. N. Prasad, "Synthesis of C₆₀-Diphenylaminofluorene Dyad with Large 2PA Cross-Sections and Efficient Intramolecular Two-Photon Energy Transfer" Chem. Commun, 17, 1854 (2002).

M. Y. Chen, Z. Bai, S. C. Tan, and M.R Unroe,, "Friction and wear scar analysis of carbon nanofiber-reinforced polymeric composite coatings on alumina/aluminum composite," Wear, 252 624 (2002).

G. P. Das, A.T.Yeates, and D. S.Dudis "An AM1 Study of the Two-Photon Absorption in Bis(styryl)benzene Derivatives," Chemical Physics Letters 361, 71-78 (2002).
G. S. He, T.-C Lin, P. N Prasad, R. Kannan, R. A. Vaia, and L.-S. Tan, "New Technique for Degenerate Two-Photon Absorption Spectral Measurements Using Femtosecond Continuum Generation," Optics Express, 10, 566, (2002).

H. Fong, W. Liu, C-S Wang and R. A. Vaia, "Generation of Electrospun Fibers of Nylon 6 and Nylon 6-Montmorillonite Nanocomposite." Polymer, 43, 775 (2002).

He, G. S.; Lin, T-C.; Prasad, P. N.; Kannan, R.; Vaia, R.A.; Tan, L-S. Study of Two-Photon Absorption Spectral Property of a Novel Nonlinear Optical Chromophore Using Femtosecond Continuum Journal of Physical Chemistry B (2002), 106(43), 11081-11084.

Houlihan, F., M. Kunnavakham, A. Liddle, P. Mirau, O. Nalamasu, and J Rogers, Microlens Arrays for Optoelectronic Devices. Journal of Photopolymer Science and Technology, 2002. 15(3): p. 497-516.

S. Kumar, T. D.Dang,, F. E Arnold, A. R. Bhattacharyya, B. G. Min, X. Zhang, R. A. Vaia, C. Park, W. W. Adams, R. H. Hauge, R. E Smalley, S. Ramesh, Willis, P.A. "Synthesis, Structure, and Properties of PBO/SWNT Composites, Macromolecules", 35(24), 9039-9043 (2002).

Lu, J, P.A. Mirau, and A.E. Tonelli, Chain conformations and dynamics of crystalline polymers as observed in their inclusion compounds by solid-state NMR. Progress in Polymer Science, 2002. 27(ER2): p. 357-401.

G. B. Rossi, G. Beaucage, T. D. Dang and R. A. Vaia, "Bottom-Up Synthesis of Polymer Nanocomposites and Molecular Composites: Ionic Exchange with PMMA Latex," *Nano Letters* 2, 319 (2002).

Rossi, G. B.; Beaucage, G.; Dang, Thuy D.; Vaia, R A "Bottom-Up Synthesis of Polymer Nanocomposites and Molecular Composites: Ionic Exchange with PMMA Latex," *Nano Letters* (2002), 2(4), 319-323.

Vaia, Richard A.; Liu, Weidong "X-ray powder diffraction of polymer/layered silicate nanocomposites: model and practice." *Journal of Polymer Science, Part B: Polymer Physics* (2002), 40(15), 1590-1600.

Vaia, R. A.; Lincoln, D. "Mesoscopic structure of polymer-inorganic nanocomposites." *ACS Symposium Series* (2002), 804(Polymer Nanocomposites), 99-115.

W. Xie, R. Xie, W.-P. Pan, D. Hunter, B. Koene, L.-S. Tan and R. A. Vaia, "Thermal Stability of Quaternary Phosphonium Modified Montmorillonites," *Chemistry of Materials* 14, 4837 (2002).

Yang, S., Y. Horibe, C.H. Chen, P. Mirau, T. Tatry, P. Evans, J. Grazul, and E.M. Dufresne, Ordered Hydrophobic Organosilicates Templated by Block Copolymers. *Chemistry of Materials*, 2002. 14(12): p. 5173-5178.

2003

V. N. Balbyshev, Kelly L. Anderson, A. Snsawat, B. L. Farmer, and M. SDonley, "Modeling of Nano-sized Macromolecules in Silane-based Self-assembled Nanophase Particle (SNAP) Coatings." *Progress in Organic Coatings*, 47(3-4), 337, 2003.

Jong-Beom Baek and Loon-Seng Tan, "Linear-Hyperbranched Copolymerization as a Tool to Modulate Thermal Properties and Crystallinity of Poly(Ether-Ketones)," *Polymer*, 44, 3451 (2003).

Jong-Beom Baek and Loon-Seng Tan, "Improved Syntheses of Poly(oxy-1,3-phenylenecarbonyl-1,4-phenylene) and Related Poly(ether-ketones) Using Polyphosphoric Acid/P₂O₅ as Polymerization Medium," *Polymer*, 44, 4135 (2003).

Jong-Beom Baek, John B. Ferguson, and Loon-Seng Tan, "Room-temperature Free-Radical-Induced Polymerization of 1,1'-(Methylenedi-1,4-phenylene)bismaleimide via a Novel Diphenylquinoxaline-Containing Hyperbranched Aromatic Polyamide" *Macromolecules* 36, 4385 (2003).

Blaudeau, J-P.; Franck, T.; Yeates, A. T.; Dudis, D. S.; 'Computational Models for the 5,6-Bridged Complexes of C122: Neutral, Anionic, and Di-Anionic Forms," *Proc. Electrochem. Soc.*, 2003-15, 411-421 (2003).

Thuy D. Dang, P. T. Mather, M. D. Alexander, M. D. Houtz, R. J Spry and F. E. Arnold, "Synthesis of aromatic benzoxazole polymers for high T_g, low dielectric properties," *Proceedings of the Second International Symposium on Polyimides and Other High*

Temperature Polymers: Synthesis, Characterization and Applications, (K.L. Mittal, Ed.), (Ridderprint BV, Netherlands, Publ.), pp. 205-223 (2003).

Dang, Thuy D.; Dalton, Matthew J; Williams, Larry D.; Reitz, Thomas L.; Durstock, Michael F.; Venkatasubramanian, N.; Arnold, Fred E Sulfonated benzazole polymers as PEMs for fuel cells. *Polymeric Materials Science and Engineering* (2003), 89 508-509.

M. F. Durstock, R. J Spry, J W. Baur, B. E Taylor, L. Y. Chiang , "Investigation of Electrostatic Self-Assembly as a Means to Fabricate and Interfacially Modify Polymer-Based Photovoltaic Devices", *Jurnal of Applied Physics*, 94(5), 3253-3259 (2003).

Ganguli, Sabyasachi; Dean, Derrick; Jordan, Kelvin; Price, Gary; Vaia, Richard. Chemorheology of cyanate ester-organically layered silicate nanocomposites. *Polymer* (2003), 44(22), 6901-6911.

Ganguli, S; Dean, D.; Jordan, K.; Price, G. Vaia, R. Mechanical properties of intercalated cyanate ester-layered silicate nanocomposites. *Polymer* (2003), 44(4), 1315-1319.

S. Ganguli, D. Dean, K. Jordan, G. Price, R. Vaia,, "Mechanical properties of intercalated cyanate ester-layered silicate nanocomposites," *Polymer*, 44, 1315-1319(2003).

He, Guang S; Lin, Tzu-Chau; Hsiao, Vincent K. S; Cartwright, Alexander N.; Prasad, Paras N.; Natarajan, L. V.; Tondiglia, V. P.; Jakubiak, R.; Vaia, R. A.; Bunning, T. J Tunable two-photon pumped lasing using a holographic polymer-dispersed liquid-crystal grating as a distributed feedback element *Applied Physics Letters* (2003), 83(14), 2733-2735.

G. S. He, T. C. Lin, V. K. S. Hsiao, A. N. Cartwright, P. N. Prasad, L. V. Natarajan, V. P. Tondiglia, R. Jakubiak, R. A. Vaia, and T. J Bunning, "Tunable Two-photon Pumped Lasing Using a Holographic Polymer-Dispersed Liquid-Crystal Grating as a Distributed Feedback Element." *Applied Physics Letters* 2003, 83, 2733-2735.

Jakubiak, R.; Bunning, T.J; Vaia, R.A.; Natarajan, L.V.; Tondiglia, Vincent P. Electrically switchable, one-dimensional polymeric resonators from holographic photopolymerization: a new approach for active photonic bandgap materials *Advanced Materials* (Weinheim, Germany) (2003), 15(3), 241-244.

Jbanputra, Manish C.; Durstock, Michael F.; Clarson, Stephen J Investigation of plasma polymerized benzene and furan thin films for application in opto-electronic devices. *Jurnal of Applied Polymer Science* (2003), 87(3), 523-528.

Tzu-Chau Lin, Guang S. He, Paras N. Prasad and Loon-Seng Tan, "Nonlinear Absorption Spectral Properties of Asymmetrically Substituted Stilbenoid Chromophores," submitted to *Phys. Chem. Chem. Phys.*

Lyuksyutov, S.F.; Vaia, R.A.; Paramonov, P.B.; Juhl, S; Waterhouse, L.; Ralich, R.M.;

Sigalov, G.; Sancaktar, E. Electrostatic nanolithography in polymers using atomic force microscopy. *Nature Materials* (2003), 2(7), 468-472.

Lyuksyutov, Sergei F.; Paramonov, Pavel B.; Juhl, Shane; Vaia, Richard A.. Amplitude-modulated electrostatic nanolithography in polymers based on atomic force microscopy. *Applied Physics Letters* (2003), 83(21), 4405-4407.

M. Schwartz, L. R. Peebles, R. J Berry, and P. Marshall, "A Computational Study of Chlorofluoro-methyl Radicals," *J Chem. Phys.* 118, 557 (2003).

Sinsawat, Anuchai; Anderson, Kelly L.; Vaia, Richard A.; Farmer, B. L Influence of polymer matrix composition and architecture on polymer nanocomposite formation: Coarse-grained molecular dynamics simulation. *Journal of Polymer Science, Part B: Polymer Physics* (2003), 41(24), 3272-3284

Jm C. Spain, Shirley F. Nishino, Loon-Seng Tan, Bernard Witholt, and Wouter A. Duetz, "Production of 6-Phenylacetylene Picolinic Acid from Diphenylacetylene by a Toluene-degrading *Acinetobacter*," *J Ind. Microbiol. Biotechnol.* 2003, 69, 4037.

Benjamin Y.Tang, Alexander JJng, Christopher Y. Li, Zhihao Shen, David H. Wang, Frank W. Harris, and Stephen Z. D .Cheng, "Role of Polymorphous Metastability in Crystal Formation Kinetics of 2,3,6,7,10,11-Hexa(4'-Octyloxybenzoyloxy)Triphenylene Discotic Molecules." *Crystal Growth & Design* 2003, 3(3), 375-382.

Loon-Seng Tan, Ramamurthi Kannan, Michael J Matuszewski, Ida J Khur, William A. Feld, Thuy D. Dang, Ann G. Dombroskie, Richard A. Vaia, Stephen J Clarson, Guang S. He, Tzu-Chau Lin, and Paras N. Prasad *SPIE Proceedings*, 4797, 171 (2003).

Vaia, R.A.; Liu, W.; Koerner, H. "Analysis of Small Angle Scattering of Suspensions of Organically-Modified Montmorillonite: Implications to Phase Behavior of Polymer Nanocomposites" *Journal of Polymer Science, Part B: Polymer Physics* (2003) 41, 3214-3236.

Yang, Junbing; Dai, Liming; Vaia, Richard A. Multicomponent interposed carbon nanotube micropatterns by region-specific contact transfer and self-assembling. *Journal of Physical Chemistry B* (2003), 107(45), 12387-12390.

Yang, S.; Mirau, P.; Sun, J; Gidley, D. W., Characterization of nanoporous ultra low-k thin films templated by copolymers with different architectures, *Radiation Physics and Chemistry*, 2003, vol. 68, no. 3-4, pp. 351-356

2004

D. Anglos, A. Stassinopoulos, R.N. Das, G. Zacharakis, M. Psyllaki, R. Jakubiak, R. A. Vaia, E. P. Giannelis, S. H. Anastasiadis "Random Laser Action in Organic/Inorganic Nanocomposites," *J Optic Soc. Am. B*, (2004) 12(1), 208-212.

S. J Bai, C. C. Wu, T. D. Dang, F. E. Arnold and B. Sankaran, "Tunable and white light-emitting diodes of monolayer fluorinated benzoxazole graft copolymers", *Appl. Phys. Lett.*, 2004, 84(10), 1656.

J-B. Baek, C. B. Lyons and L.-S. Tan. "Grafting of Vapor-Grown Carbon Nanofibers via in-Situ Polycondensation of 3-Phenoxybenzoic Acid in Poly(phosphoric acid)". *Macromolecules*, 37, 8278-8285 (2004).

Jong-Beom Baek, Christopher Lyons, and Loon-Seng Tan "Covalent modification of vapor-grown carbon nanotubes (VGCNF) via direct Friedel-Crafts acylation in polyphosphoric acid." *J Mater. Chem.* 2004, 14, 2052-2056.

D. W. Brousmiche, J M. Serin, J M. J Fréchet, G. S. He, T.-C. Lin, S.-J Chung, P. N. Prasad, R. Kannan, and L.-S. Tan, "Fluorescence Resonance Energy Transfer in Novel Multiphoton Absorbing Dendritic Structures" *J Phys. Chem. B* 2004, 108, 8592-8600.

T. D. Dang, M. J Dalton, N. Venkatasubramanian, J A. Johnson, C. A. Cerbus and W. A. Feld. "Synthesis and characterization of polyaryleneetherketone triphenylphosphine oxides incorporating cycloaliphatic/cage hydrocarbon structural units". *Journal of Polymer Science, Part A: Polymer Chemistry*, 42, 6134-6142 (2004).

G. P. Das, A. T. Yeates and D. S. Dudis, "Ab Initio Fragment Orbital Theory (AFOT): Application to Some Two-Photon-Absorbing (TPA) Molecules," *Chem. Phys. Lett.*, 393(1-3), 76-80 (2004).

W. R. Dichtel, J M. Serin, C. Edder, J M. J Fréchet, M. Matuszewski, L.-S. Tan, T. Y. Ohulchanskyy, and P. N. Prasad, "Singlet Oxygen Generation via Two-Photon Excited FRET." *J Am. Chem. Soc.* 2004, 126, 5380-5381.

He, Guang S.; Lin, Tzu-Chau; Dai, Janming; Prasad, Paras N.; Kannan, Ramamurthi; Dombroskie, Ann G.; Vaia, Richard A.; Tan, Loon-Seng, "Degenerate two-photon-absorption spectral studies of highly two-photon active organic chromophores. *Journal of Chemical Physics* (2004), 120(11), 5275-5284.

Ha, Y-H; Vaia, R. A.; Lynn, W. F.; Costantino, J P.; Shin, J; Smith, A. B.; Matsudaira, P. T.; Thomas, E. L., "Three-Dimensional Network Photonic Crystals via Cyclic Size Reduction/Infiltration of Sea Urchin Exoskeleton", *Advanced Materials* (Weinheim, Germany), 16(13), 1091-1094, 2004.

Jakubiak, R.; Natarajan, L. V.; Tondiglia, V.; He, G. S.; Prasad, P. N.; Bunning, T. J.; Vaia,

R. A., "Electrically Switchable Lasing from Pyrromethene 597 Embedded Holographic-Polymer Dispersed Liquid Crystals", *Applied Physics Letters*, 85(25), 6095-6097, 2004.

Juhl, S.; Phillips, D.; Vaia, R. A.; Lyuksyutov, S. F.; Paramonov, P. B., "Precise Formation of Nanoscopic Dots on Polystyrene Film Using Z-Lift Electrostatic Lithography", *Applied Physics Letters*, 85(17), 3836-3838, 2004.

Kannan, Ramamurthi; He, Guang S.; Lin, Tzu-Chau; Prasad, Paras N.; Vaia, Richard A.; Tan, Loon-Seng. Toward Highly Active Two-Photon Absorbing Liquids. Synthesis and Characterization of 1,3,5-Triazine-Based Octupolar Molecules. *Chemistry of Materials* (2004), 16(1), 185-194.

Hilmar Koerner, Gary Price, Nathan A. Pearce, Max Alexander, Richard A. Vaia Remotely-Actuated Polymer Nanocomposites: Stress-recovery of carbon nanotubes filled thermoplastic elastomers. *Nature Materials*, 3, 115-120 (2004).

Hilmar Koerner, J David Jacobs, David W. Tomlin, John Busbee, Richard A. Vaia, Tuning Polymer Nanocomposite Morphology: AC Electric Field Manipulation of Epoxy – Montmorillonite (Clay) Suspensions. *Adv. Materials* 16, 297-302 (2004).

Tzu-Chau Lin, Guang S. He, Paras N. Prasad and Loon-Seng Tan, "Nonlinear Absorption Spectral Properties of Asymmetrically Substituted Stilbenoid Chromophores." *J Mater. Chem.* 2004,14, 982-991.

Derek M. Lincoln, Ramanan Krishnamoorti Richard A. Vaia Isothermal Crystallization of Nylon 6/Montmorillonite Nanocomposites. *Macromolecules*, (2004) 37(12) 4554-4561.

Naik, Rajesh R.; Jones, Sharon E.; Murray, Christopher J.; McAuliffe, Joseph C.; Vaia, Richard A.; Stone, Morley O., Peptide templates for nanoparticle synthesis derived from polymerase chain reaction-driven phage display, *Advanced Functional Materials* (2004), 14(1), 25-30.

P. A. Padmawar, T. Canteenwala, S. Verma, L.-S. Tan and L. Y. Chiang. "Synthesis and Photophysical Properties of C60-Diphenylaminofluorene Dyad and Multiads". *Journal of Macromolecular Science, Pure and Applied Chemistry*, A41, 1387-1400 (2004).

S.-Y. Park, H. Koerner, S. Putthanarat, R. Ozisik, S. Juhl, B. L. Farmer and R. K. Eby. "Structure of poly(p-phenylenebenzobisoxazole) (PBZO) and poly(p-phenylenebenzobisthiazole) (PBZT) for proton exchange membranes (PEMs) in fuel cells". *Polymer*, 45, 49-59 (2004).

Pender, Mark J; Sowards, Laura A.; Maruyama, Benji; Vaia, Richard A.; Stone, Morley O. Spin-On Catalyst: Straightforward and Flexible Route to Substrate-Grown Single Wall Carbon Nanotubes. *Chemistry of Materials* (2004), 16(13), 2544-2550.

S. Putthanarat, R. K. Eby, R. R. Naik, S. B. Juhl, M. A. Walker, E. Peterman, S. Ristich, J. Magoshi, T. Tanaka, M. O. Stone, B. L. Farmer, C. Brewer and D. Ott. "Nonlinear optical transmission of silk/green fluorescent protein (GFP) films". *Polymer*, 45, 8451-8457 (2004).

J E Rogers, J E Sagle, D. G. McLean, R. L. Sutherland, B. Sankaran, R. Kannan, L.-S. Tan, and P. A. Fleitz, "Understanding the One-Photon Photophysical Properties of a Two-Photon Absorbing Chromophore." *J Phys. Chem. A* 2004, 108, 5514-5520.

Schwartz, M.; Srinivas, G. N.; Yeates, A. T.; Berry, R. J.; Dudis, D. S.; "The Electronic Properties of Polyacetylene-Polymethineimine Block Copolymers," *Synth. Metals*, 143(2), 229-236 (2004).

A.P. Smith, Rachel R. Smith, Barney E Taylor, Michael F. Durstock, "An Investigation of Poly(Thienylene Vinylene) in Organic Photovoltaic Devices", *Chemistry of Materials*, 16, 4687-4692, 2004.

H. Sun, N. Venkatasubramanian, M. D. Houtz, J E Mark, S C. Tan, F. E Arnold and C. Y. C. Lee. "Molecular composites by incorporation of a rod-like polymer into a functionalized high-performance polymer, and their conversion into microcellular foams". *Colloid and Polymer Science*, 282, 502-510 (2004).

H. Sun, J E Mark, S. C. Tan, N. Venkatasubramanian, M. D. Houtz, F. E Arnold and C. Y. C. Lee. "Microcellular foams from some high-performance thermoplastics and their composites". *Nonlinear Optics, Quantum Optics*, 31, 1-29 (2004).

Vaia, R. A.; Wagner, H. D., "Framework for Nanocomposites", *Materials Today* (Oxford, United Kingdom), 7(11), 32-37, 2004.

Wagner, H. D.; Vaia, R. A., "Nanocomposites: Issues at the Interface", *Materials Today* (Oxford, United Kingdom), 7(11), 38-42, 2004.

2005

K. L. Anderson, B. L. Farmer and R. K. Eby. "Epitaxy of folds in polyethylene crystals: molecular mechanics investigation". *Polymer*, 46, 8703-8707 (2005).

K. L. Anderson, A. Sinsawat, R. A. Vaia and B. L. Farmer. "Control of silicate nanocomposite morphology in binary fluids: coarse-grained molecular dynamics simulations". *Journal of Polymer Science, Part B: Polymer Physics*, 43, 1014-1024 (2005).

J-B. Baek, S.-Y. Park, G. E. Price, C. B. Lyons and L.-S. Tan. "Unusual thermal relaxation of viscosity-and-shear-induced strain in poly(ether-ketones) synthesized in highly viscous polyphosphoric acid/P₂O₅ medium". *Polymer*, 46, 1543-1552 (2005).

M. F. Durstock, D. Friedman, R. Gaudiana, A. Rockett, editors, "Materials for Photovoltaics", MRS Symposium Proceedings, Volume 836, 2005.

Fossum, Eric; Tan, Loon-Seng, "Geometrical influence of AB_n monomer structure on the thermal properties of linear-hyperbranched ether-ketone copolymers prepared via an AB+ AB_n route" *Polymer* (2005), 46(23), 9686-9693.

He, Guang S.; Prasad, Paras N.; Chiang, Long Y. "Synthesis of C₆₀-diphenylaminofluorene dyads with two-photon absorbing characteristics." *Synthetic Metals*, (2005), 154(1-3), 185-188.

Hsiao, V. K. S.; Lu, C.; He, G. S.; Pan, M.; Cartwright, A. N.; Prasad, P. N.; Jakubiak, R.; Vaia, R. A.; Bunning, T. J., "High Contrast Switching of Distributed-Feedback Lasing in Dye-Doped H-PDLC Transmission Grating Structures", *Optics Express*, 13(10), 3787-3794, 2005.

Justice, R. S.; Schaefer, D. W.; Vaia, R. A.; Tomlin, D. W.; Bunning, T. J., "Interface Morphology and Phase Separation in Polymer-Dispersed Liquid Crystal Composites", *Polymer*, 46(12), 4465-4473, 2005.

Koerner, H.; Liu, W.; Alexander, M.; Mirau, P.; Dowty, H.; Vaia, R. A., "Deformation-Morphology Correlations in Electrically Conductive Carbon Nanotube-Thermoplastic Polyurethane Nanocomposites", *Polymer*, 46(12), 4405-4420, 2005.

H. Koerner, E. Hampton, D. Dean, Z. Turgut, L. Drummy, P. Mirau and R. Vaia. "Generating Triaxial Reinforced Epoxy/Montmorillonite Nanocomposites with Uniaxial Magnetic Fields". *Chemistry of Materials*, 17, 1990-1996 (2005).

Lincoln, D. M.; Fong, H.; Vaia, R. A. "Nanocomposites for Extreme Environments", *ACS Symposium Series*, 891(Defense Applications of Nanomaterials), 82-101, 2005.

Lyuksyutov, S. F.; Paramonov, P. B.; Vaia, R. A. "Free Energy Analysis of System Comprising Biased Atomic Force Microscope Tip, Water Meniscus and Dielectric Surface", *Condensed Matter*, 1-4, 2005.

R. B. Pandey, K. L. Anderson, H. Heinz and B. L. Farmer. "Conformation and dynamics of a self-avoiding sheet: bond-fluctuation computer simulation". *Journal of Polymer Science, Part B: Polymer Physics*, 43, 1041-1046 (2005).

S.-Y. Park, S.-C. Moon, T. D. Dang, N. Venkatasubramanian, J. Lee and B. L. Farmer. "Crystal Structure of Poly(1,5-naphthalenebenzobisthiazole)". *Macromolecules*, 38, 1711-1716 (2005).

S.-Y. Park, S.-C. Moon, T. D. Dang, N. Venkatasubramanian, J.-w. Lee and B. L. Farmer. "The crystal structure of poly(2,6-naphthalenebenzobisthiazole)". *Polymer*, 46, 5630-5636 (2005).

Park, S-Y; Cho, Y-H; Vaia, R. A. "Three-Dimensional Structure of the Zone-Drawn Film of the Nylon-6/Layered Silicate Nanocomposites", *Macromolecules*, 38(5), 1729-1735, 2005.

Patil, A.; Vaia, R.; Dai, L., "Surface Modification of Aligned Carbon Nanotube Arrays for Electron Emitting Applications", *Synthetic Metals*, 154(1-3), 229-232, 2005.

Pikas, David J; Walker, Mark A.; Brewer, Christopher D.; Sankaran, Bala; Tan, Loon-Seng; Kuzyk, Mark G.; Kirkpatrick, Sean M.; Powers, Peter E. "Background host effects on the nonlinear photophysical properties of a two-photon absorbing dye." *Proceedings of SPIE- The International Society for Optical Engineering* (2005), 5989 (Technologies for Optical Countermeasures II; Femtosecond Phenomena II; and Passive Millimetre-Wave and Terahertz Imaging II), 199-208.

Pozhar, L. A.; Yeates, A. T.; Szmulowicz, F.; Mitchel, W. C., "Small atomic clusters as prototypes for sub-nanoscale heterostructure units with pre-designed electronic properties," *Europhysics Letters*, 7(13), 380-386(2005).

Pozhar, Liudmila A.; Yeates, Alan T.; Szmulowicz, Frank; Mitchel, William C., "Virtual fabrication of small Ga-As/P and In-As/P clusters with predesigned electronic pattern structure," *MRS Symposium Proceedings*, 829(Progress in Compound Semiconductor Materials IV - Electronic and Optoelectronic Applications), 49-54(2005).

Pozhar, Liudmila A.; Yeates, Alan T.; Szmulowicz, Frank; Mitchel, William C., "Small 'magnetic' clusters of Ga and In with As and V," *MRS Symposium Proceedings*, 830(Materials and Processes for Nonvolatile Memories), 293-298(2005).

Radloff, C.; Vaia, R. A.; Brunton, J; Bouwer, G. T.; Ward, V. K. "Metal Nanoshell Assembly on a Virus Bioscaffold", *Nano Letters*, 5(6), 1187-1191, 2005.

Schaefer, D. W.; Justice, R. S.; Koerner, H.; Vaia, R.; Zhao, C.; Yang, M.; Vale, J., "Large-Scale Morphology of Dispersed Layered Silicates", *Materials Research Society Symposium Proceedings*, Volume Date 2004, 840(Neutron and X-Ray Scattering as Probes of Multiscale Phenomena), 57-62, 2005.

H. Sun, J E Mark, S. C. Tan, N. Venkatasubramanian, M. D. Houtz, F. E. Arnold and C. Y. C. Lee. "Microcellular foams from some high-performance composites". *Polymer*, 46, 6623-6632 (2005).

T. Uchida, T. Dang, B. G. Min, X. Zhang and S. Kumar. "Processing, structure, and properties of carbon nano fiber filled PBZT composite fiber". *Composites, Part B: Engineering*, 36B, 183-187 (2005).

Li, L.; Yang, J; Vaia, R; Dai, L., "Multicomponent Micropatterns of Carbon Nanotubes", *Synthetic Metals*, 154(1-3), 225-228, 2005.

2006

Jong-Beom Baek and Loon-Seng Tan, "Hyperbranched Poly(phenylquinoxaline-ether-ketone) Synthesis in Poly(Phosphoric acid)/P₂O₅ Medium: Optimization and Some Interesting Observations," *Macromolecules*, (2006) 39, 2794-2803.

Long Chiang, "Large Cross-section Enhancement and Intramolecular Energy Transfer Upon Multiphoton Absorption of Hindered Diphenylaminofluorene-C₆₀ Dyads and Triads," *Mater. Chem.* (2006) 1366-1378.

Lawrence F. Drummy, Hilmar Koerner, Barry L. Farmer Richard A. Vaia, Advanced morphology characterization of clay-based polymer nanocomposites, CMS Workshop Lecture Series, Volume 14, Clay Minerals Society, 2006 in press.

Mark M. Green, Jeffery L. White, Peter Mirau and Meir H. Scheinfeld. "C-H to O Hydrogen Bonding: The Attractive Interaction in the Blend between Polystyrene and Poly(vinyl methyl ether)". *Macromolecules*, 39, 5971-5973 (2006).

Hendrik Heinz, R. A. Vaia, R. Krishnamoorti, B. L. Farmer Self-Assembly of Alkylammonium Chains on Montmorillonite: Effect of Chain Length, Head Group Structure, and Cation Exchange Capacity Chemistry of Materials, 2006, submitted.

Hilmar Koerner, Devesh Misra, Ashley Tan, Lawrence Drummy, Peter Mirau and Richard Vaia. "Montmorillonite-thermoset nanocomposites via cryo-compounding". *Polymer*, 47, 3426-3435 (2006).

Wei Lu, Hilmar Koerner Richard Vaia Effect of Electric Field on Exfoliation of Nanoplates, Applied Phys Letters, submitted 2006.

Nadeau, Lloyd J; Spain, Jm C.; Kannan, Ramamurthi; Tan, Loon-Seng. "Conversion of 2-(4-carboxyphenyl)-6-nitrobenzothiazole to 4-(6-amino-5-hydroxybenzothiazol-2-yl)benzoic acid by a recombinant E. coli strain". *Chemical Communications*(Cambridge, United Kingdom) 2006, (5), 564-565.

Michael A. Oar, William R. Dichtel, Jason M. Serin, Jean M. J Fréchet, Jy E Rogers, Jonathan E. Sagle, Paul A. Fleitz, Loon-Seng Tan, Tymish Y. Ohulchanskyy, and Paras N. Prasad "Metallated Porphyrin Materials for Tuned Photosensitization of Singlet Oxygen via Two-Photon Excited FRET", *Chemistry of Materials*(2006) 18, 3682-3692.

Oh, Se-Jin; Lee, Hwa-Jeong; Keum, Dong-Ki; Lee, Seong-Woo; Wang, David H.; Park, Soo-Young; Tan, Loon-Seng; Baek, Jong-Beom. "Multiwalled carbon nanotubes and nanofibers grafted with polyetherketones in mild and viscous polymeric acid." *Polymer* (2006), 47(4), 1132-1140.

Prashant A. Padmawar, Jby E Rogers, Guang S. He, Long Y. Chiang, Taizoon Canteenwala, Loon-Seng Tan, Qingdong Zheng, Jbnathan E. Slagle, Daniel G. McLean, Paul A. Fleitz, and Paras N. Prasad "Large Cross-section Enhancement and Intramolecular Energy Transfer upon Multiphoton Absorption of Hindered Diphenylaminofluorene-C₆₀ Dyads and Triads" *Chemistry of Materials* (2006) 18, 4065-4074.

Haihu Qin, Patrick T. Mather, Jng-Beom Baek and Loon-Seng Tan, "Modification of bisphenol-A based bismaleimide resin (BPA-BMI) with an allyl-terminated hyperbranched polyimide (AT-PAEKI)," *Polymer* (2006), 47(6), 2813-2821.

R. R. Smith, A. P. Smith, J T. Stricker, B. E. Taylor, M. F. Durstock "Layer-by-Layer Assembly of PEDOT:PSS – Poly(3,4 – ethylenedioxythiophene) : Poly(styrene sulfonate)", submitted, *Macromolecules*

R. Vaia, J Maguire, Polymer Nanocomposites with Prescribed Morphology: Going Beyond NanoParticle-Filled Polymers, 2006, submitted to Korean Polymer.

Wang, David H.; Baek, Jng-Beom; Nishino, Shirley F.; Spain, Jm C.; Tan, Loon-Seng. "Thermally reactive phenylethynyl-terminated bis(benzylester) and bis(amide) monomers based on semi-enzymatically produced 6-phenylethynyl picolinic acid." *Polymer* (2006), 47(4), 1197-1206.

David H. Wang, Jng-Beom BAEK, Loon-Seng Tan "Grafting of Vapor-Grown Carbon Nanofibers (VGCNF) with a Hyperbranched Poly(ether-ketone)" *Mater. Sci. Eng. B* (2006) 132, 103-107.

X. Zheng, G. Forest, R.A. Vaia, M. Arlen, R. Zhou, Shear-guided anisotropic geometrical percolation in nano-rod ensembles, *Rheologica Acta* submitted 2006.

2007

Junbing Yang, Liangti Qu, Ye Zhao, Qiuhong Zhang, Liming Dai, Jeffery W. Baur, Benji Maruyama, Rich A. Vaia, Eunsung Shin, P. Terrence Murray, Hongxia Luo, Zhi-Xin Guo, Multicomponent and Multidimensional Carbon Nanotube Micropatterns by Dry Contact Transfer *Journal of Nanoscience and Nanotechnology* Vol.7, 1– 8, 2007 in press.

5.1 Publications (Unrefereed):

2001

Ganguli, S.; Dean, D.; Jordan, K. Price, G.; Vaia, R. Cyanate ester resins - a candidate for high temperature space applications" *Proceedings of the NATAS Annual Conference on Thermal Analysis and Applications* (2001), 29th 250-256.

Xie, W.; Pan, W-P; Vaia, R. A study of thermal degradation mechanism of organically

modified montmorillonite Proceedings of the NATAS Annual Conference on Thermal Analysis and Applications (2001), 29th 264-269.

2002

J-B. Baek, and L.-S. Tan "Synthesis of Hyperbranched Poly(ether-ketone) Containing Quinoxaline Moiety from An AB₂ Monomer in PPA/P₂O₅" Polym. Prepr. 43(1), 515 (2002)

J-B. Baek, and L.-S. Tan "Synthesis of Poly(etherketones) and A Polyethersulfone using PPA/P₂O₅ as Polymerization Medium." Polym. Prepr. 43(1), 535 (2002).

J-B. Baek, S. B. Juh, C. B. Lyons, B. L Farmer, L.-S. Tan "Synthesis and Properties of Polyaryleneetherketone (PEK)-Co-Polybenzobisthiazole (PBZT)-co-Polyaryleneetherketone (PEK) ABA Triblock copolymers" Polym. Prepr. 43(2), 1130 (2002).

M. J Dalton, W. A. Feld, J A. Johnson, N. C. Thiesing, C. A. Cerbus, N. Venkatasubramanian and T. D. Dang, "Synthesis and Characterization of Polyaryleneetherketone Phosphine Oxides Incorporating Cycloaliphatic Units for Space Thermal Control Coatings," Polym. Prepr., 43(2), 1150 (2002).

T. D. Dang, P. T. Mather, M. D. Alexander, R. J Spry and F. E Arnold, "Synthesis of Aromatic Benzoxazole Polymers For High Tg Low Dielectric Properties," *Proceedings of the Second International Polyimide Conference* (2002)

T. D. Dang, M. J Matuszewski, M. J Dalton, R. Kannan, J E Franklin, M. F. Durstock, L.-S. Tan and F. E Arnold, "Synthesis and Optical Characterization of 1H-Pyrazole-Based 6F-Benzoxazole Polymers Incorporating a Two-Photon Absorption Chromophore," *Polym. Prepr.*, 43(1), 102 (2002).

T. D. Dang, N. Venkatasubramanian, A. E Talicska, S.-Y. Park and F. E Arnold, "Synthesis and Characterization of Rigid-Rod Benzobisazole Polymers Containing Naphthalene-2,6- and 1,5- Diyl Units," Polym. Prepr., 43(1), 660 (2002).

Ganquli, S.; Dean, D.; Vaia, R "Mechanical properties of intercalated cyanate ester-layered silicate nanocomposites. " *Polymeric Materials Science and Engineering* (2002), 87 94-96

Giannelis, E. P.; Stasinopoulos, A.; Psyllaki, M.; Zacharakis, G.; Das, R. N.; Anglos, D.; Anastasiadis, S. H.; Vaia, R. A.. Random lasers based on organic-inorganic hybrids. *Materials Research Society Symposium Proceedings* (2002), 726(Organic/Inorganic Hybrid Materials-2002), 11-19.

Gelfer, M. Y.; Sics, I.; Liu, L.; Choi, W.-J; Wang, G. Z.-G.; Vaia, R. A.; Kim, S.-C.; Chu, B.; Hsiao, B. S. "Control of structure and properties in nanocomposites comprising semicrystalline polymer matrix and clay." *Polymeric Materials Science and Engineering* (2002), 86 427-428.

R. Jakubiak, R. A. Vaia, T. J. Bunning, L. V. Natarajan, V. P. Tondiglia, "Switchable Photonic Band GAP Lasing Resonators from Holographic Polymerization." *Polym. Prepr.* **43**(2), 546-547(2002).

Lu, J., P.A. Mirau, S. Nojima, and A.E. Tonelli, NMR Studies of the Dynamics of Homo- and Block-Copolymer Poly(epsilon-caprolactone) Chains in Their Inclusion Compounds with alpha- and gamma-CDs. *ACS Symposium Series*, 2002. 834: p. 43-57.

Mirau, P.A. and S. Yang, Solution and Solid-State NMR Characterization of Ethylene Oxide-Propylene Oxide Composites for Ultra-Low Dielectric Constant Applications. *ACS Symposium Series*, 2002. 834: p. 22-31.

S.-Y. Park, J. Lee, N. Venkatasubramanian, T. D. Dang, B. L. Farmer and F. E. Arnold, "Structural Studies on Naphthalene-Based Rigid-Rod Benzobisazole Polymers," *Polym. Prepr.*, **43**(1), 248 (2002).

H. Sun, N. Venkatasubramanian, J. E. Mark, F. E. Arnold, "Study of Modified Polysulfone/Polybenzimidazole Composites and their Application as Microcellular Foams," *Polym. Prepr.*, **43**(1), 471 (2002).

Tan, L.-S.; Kannsn, R.; Matuszewski, M.; Vaia, R.A. et al. Functionalization of Heterocyclic DiPhenylamino-based TPA Materials for Microfabrication, Data Storage and UpConverted Imaging, *SPIE Proceedings*, July 2002, in press

Vasiliu, E.; Wang, C.-S.; Vaia, R.A.. "Preparation of optically transparent films of poly(methyl methacrylate) (PMMA) and montmorillonite." *Materials Research Society Symposium Proceedings* (2002), 703(Nanophase and Nanocomposite Materials IV), 243-248.

J. Wu, G. M. Kim, P. T. Mather, N. Venkatasubramanian, T. D. Dang and F. E. Arnold, "Rheology and Morphology of Molecular Composites from Sulfonated Rigid-rods," *Polym. Prepr.*, **43**(1), 1051 (2002).

Yang, S., Y. Horibe, C. Chen, P. Mirau, and T. Tatry, Ordered Hydrophobic Organosilicates Templated By Block Copolymers. *Polymer Preprints*, 2002. **43**(2): p. 386-387.

2003

Dean, D.; Abdalla, M.O.; Ganguli, S.; Jbse, M.; Campbell, S.; Gillman, J.; Awad, W.H.; Vaia, R. High temperature thermoset nanocomposites. *Polymeric Materials Science and Engineering* (2003), 89 729-732.

Z. Bai, L. D. Williams, M. F. Durstock and T. D. Dang, "Properties And Proton Conductivities Of Highly Sulfonated Polyarylene-thioethersulfones For Fuel Cells", *Poly. Prep., (ACS)*, 2004, **45**(1), 60

Jong-Beom Baek, Christopher B. Lyons and Loon-Seng Tan, "Synthesis and properties of hyperbranched polyaryleneetherketone (PEK)-co-polybenzothiazole (PBZT)-co-hyperbranched polyaryleneetherketone (PEK) ABA triblock copolymers, *Polym. Prepr.* 44(1), 825-6 (2003).

Jong-Beom Baek, Christopher B. Lyons and Loon-Seng Tan, "Polymerization of 3-phenoxybenzoic acid in the presence of vapor-grown carbon nanofiber" *Polym. Prepr.* 44(1), 925-6 (2003).

Jong-Beom Baek, Gary E. Price, Christopher B. Lyons and Loon-Seng Tan, "Thermal Relaxation of Reaction-Induced Strain in Poly(ether-ketones) Synthesized in Highly Viscous Polyphosphoric Acid/P₂O₅ as Polymerization Medium" *Polym. Prepr.* 44(2), 918 (2003).

Jong-Beom Baek, Christopher B. Lyons, Michael C. Laferriere, and Loon-Seng Tan, "Carboxylic acid-terminated hyperbranched polybenzoxazole (PBO) and its star block copolymers" *Polym. Prepr.* 44(2), 832 (2003).

Dai, Liming; Patil, Ajeeta; Vaia, Richard A.. Surface modification of aligned carbon nanotubes. AIP Conference Proceedings (2003), 685(Molecular Nanostructures), 621-634

Dang, Thuy D.; Dalton, Matthew J; Williams, Larry D.; Reitz, Thomas L.; Durstock, Michael F.; Venkatasubramanian, N.; Arnold, Fred E, Sulfonated benzazole polymers as PEMs for fuel cells. Abstracts of Papers, 226th ACS National Meeting, New York, NY, United States, September 7-11, 2003 (2003).

Thuy D. Dang, Hilmar Koerner, Matthew J Dalton, Amy M. Iacobucci, N. Venkatasubramanian and Fred E. Arnold, "Sulfo-pendent Poly(p-phenylenebenzobisazole) Rigid-Rods: Synthesis And Fiber Structural Studies", *Polymer Preprints*, 44(1), 927 (2003).

Dang, T. D.; Dalton, M. J; Williams, L. D.; Reitz, T. L.; Durstock, M. F.; Venkatasubramanian, N.; Arnold, F. E "Sulfonated benzazole polymers as PEMs for fuel cells," *Polym. Mater. Sci. Eng.* 89, 508-509 (2003).

Thuy D. Dang, Patrick T. Mather, Max D. Alexander, Marlene D. Houtz, Robert J Spry, Fred E. Arnold, "Synthesis of Aromatic Benzoxazole Polymers for High T_g, Low Dielectric Properties." *Proceedings of Polyimides and Other High Temperature Polymer Conference*, 2, 205-223 (2003).

D. Dean, M. O. Abdalla, S. Ganguli, M. Jose, S. Campbell, J. Gillman, W. H. Awad, R. Vaia, "High temperature thermoset nanocomposites." *Polym. Mater. Sci. Eng.*, 89, 729-732 (2003).

D. Dean, M. O. Abdalla, S. Ganguli, M. Jose, S. Campbell, J. Gillman, W. H. Awad, R. Vaia, "High temperature thermoset nanocomposites." International SAMPE Symposium and Exhibition 48(Advancing Materials in the Global Economy--Applications, Emerging Markets and Evolving Technologies, Book 2), 2572-2584 (2003).

M. F. Durstock, T. Anderl, "Organic Solar Cells Increase Potential For Flexible, Light-Weight Power Source and High-Efficiency Satellite Arrays", AFRL/ML Success Story, submitted July 2003.

William A. Feld, M. J. Dalton, Thuy D. Dang,; Neil C. Thiesing,; Steven C. Sins, Kathryn M. McGinty "Synthesis and polymerization of a diaminodiol containing a phosphine-oxide linkage", *Polymer Preprints*, 44(1), 898 (2003).

Eric Fossum and Loon-Seng Tan, "Hyperbranched Poly(arylene arylene phosphine oxide)s via an $A_2 + B_2$ Approach" *Polym. Prepr.* 44(1), 862-3 (2003).

Koerner H., Wang C.-S., Vaia R. A., Alexander M. D., Pearce N. A., Bentley H. Stimuli-Responsive Nanocomposites: Opening New Horizons for Aerospace Systems. *Additives 2003 Proceedings*, 12th International Meeting, 91-97 (2003)

Jakubiak, R.; Brown, D.P.; Tondiglia, V.P.; Natarajan, L.V.; He, G.; Prasad, P.; Vaia, R.A.; Bunning, T.J. Switchable and tunable solid-state dye lasers from holographic - polymer dispersed liquid crystal photonic structures *Polymeric Materials Science and Engineering* (2003), 89 46-47

Jakubiak, R.; Brown, D.P.; Vatansever, F.; Tondiglia, V.P.; Natarajan, L.V.; Tomlin, D.W.; Bunning, T.J.; Vaia, R.A. Holographic photopolymerization for fabrication of electrically switchable inorganic-organic hybrid photonic structures. *Proceedings of SPIE-The International Society for Optical Engineering* (2003), 4991(Organic Photonic Materials and Devices V), 89-97.

Mirau, P.A. and S. Yang, NMR Studies of Polymer Interfaces in Ordered Hydrophobic Organic/Inorganic Hybrids. *Polymer Preprints*, 2003. 44(1): p. 281-282.

Haihu Qin, Patrick T. Mather, Jong-Beom Baek and Loon-Seng Tan, "Modification of Bisphenol-A BMI resin (BPA-BMI) with allyl-terminated hyperbranched polyimide (AT-PAEKI)" *Polym. Prepr.* 44(1), 132-3, (2003).

2004

Jong-Beom Baek, Christopher B. Lyons, and Loon-Seng Tan, "Efficient Synthesis of Hyperbranched Polyetherketones (PEKs) from $A_3 + B_2$ Polymerization by Using Different Monomer Solubility in Reaction Medium." *Polymer Preprints* 45(1), 1032-1033 (2004).

Jong-Beom Baek, Christopher B. Lyons, and Loon-Seng Tan, "Synthesis and Optical Properties of Organo-soluble Hyperbranched Polybenzothiazoles from $A_3 + B_2$ Monomers." *Polymer Preprints* 45(2), 647-648 (2004).

Thuy D. Dang, S. Kumar, T. Uchida, K. L. Strong and N. Venkatasubramanian, "Alignment of SWNTs in Lyotropic Rigid-rod Polymer Compositions", *Proceedings of the Third International Symposium on Polyimides and other High Temperature Polymers: Synthesis, Characterization and Applications*, (K.L. Mittal, Ed.), (Ridderprint BV, Netherlands, Publ.), (in print), 2004-5

Thuy D. Dang, Z. Bai, M. J Dalton and E. Fossum, "Synthesis and Characterization of Highly Sulfonated Polyarylenethioethersulfones for Fuel Cell Applications." *Polymer Preprints* 45(1), 22-23 (2004).

Dosser, Larry; Hix, Ken; Hartke, Kevin; Vaia, Richard; Li, Mingwei. Transmission welding of carbon nanocomposites with direct-diode and Nd:YAG solid state lasers, *Proceedings of SPIE-The International Society for Optical Engineering* (2004), 5339(Photon Processing in Microelectronics and Photonics III), 465-474.

Dosser, Larry; Hix, Ken; Hartke, Kevin; Vaia, Richard; Li, Mingwei, Micromachining of carbon nanocomposites with Nd:YAG and Nd:YVO₄ frequency-converted solid state lasers, *Proceedings of SPIE-The International Society for Optical Engineering* (2004), 5339(Photon Processing in Microelectronics and Photonics III), 27-34
M. F. Durstock, T. Anderl, "Organic Solar Cells", *AFRL Technology Horizons*, 5(3), 41 (2004).

Minoru Freund, Richard Vaia, Gail Brown, Gernot Pomrenke, Nanoscience and Technology (NST) for the Air Force, AF Tech Horizons, (2004) in press.

R. Jakubiak, T. Bunning, R. Vaia, MultiComponent Active photonic structures via holographic photopolymerization, *SPIE Nanotechnology Bulletin*, 3 March 2004, Invited.

Juhl, S.; Ha, Y-H; Chan, E; Ward, V.; Smith, A.; Doakland, T.; Thomas, E. L.; Vaia, R. A., "BioHarvesting: Optical Characteristics of Wisenia Iridovirus Assemblies", *ACS Conference Proceedings*, PMSE-195, 90, 317-318, 2004.

S. Kumar, T. Uchida, T. Dang, X. Zhang and Y.-B. Park. "Polymer/carbon nanofiber composite fibers". *International SAMPE Symposium and Exhibition Proceedings*, 49, 1229-1240 (2004).

S. Kumar, T. Uchida, T. D. Dang, X. Zhang and Y-B. Park, "Polymer/Carbon Nano Fiber Composite Fibers." *Proceedings SAMPE*, Long Beach, CA, May 16-20, 2004

L.-S. Tan, R. Kannan, A. G. Dombroskie, S. R. Smko, M. D. Houtz, G. S. He, T.-C. Lin, P. N. Prasad, "Synthesis and Characterization of Thermally Cross-linkable, Two-photon Responsive Chromophores." *Polymer Preprints* 45(1), 901-902 (2004).

Radloff, C. J.; Vaia, R. A.; Brunton, J.; Ward, V.; Kalmakoff, J.; Dokland, T., "Bioscaffolds for Metal Nanostructures", *SPIE Conference Proceedings*, p. 60-67, Plasmonics: Metallic Nanostructures and Their Optical Properties II; Naomi J Halas, Thomas R. Huser; Eds., October 2004.

J M. Serin, M. A. Oar, W. R. Dichtel, Y. Tao, B. A. Helms, J M. J Fréchet, T. Y. Ohulchanskyy, P. N. Prasad, R. Kannan, L.-S. Tan, "Novel Dendritic Oxygen Photosensitizers Utilizing Single- and Multi-photon excitation in both organic and aqueous solutions." *Polym. Mater. Eng. Sci.* 91, 59-60 (2004).

R. L. Sutherland, M. E. Brant, D. G. McLean, J E Rogers, B. Sankaran, S. E. Kirkpatrick and P. A. Fleitz. "Excited state absorption in a strongly two-photon absorbing neat organic material". *Trends in Optics and Photonics Proceeding*, 96/B, CFF6/1-CFF6/3 (2004).

Richard Vaia, Hilmar Koerner, Max Alexander, Stimuli Responsive Polymer Nanocomposites: Towards Active Materials and Processing. IUPAC, MACRO 2004 Conference Proceeding, 2004

N. Venkatasubramanian, Thuy D. Dang, Matthew J Dalton, Larry D. Williams, Heather J Bentley, Robert P. Monter, and Sandra Fries-Carr, "Advanced Polymer Dielectrics for Capacitive Energy Storage." *Polymer Preprints* 45(1), 931-932 (2004).

D. H. Wang, J.-B. Baek, H. Qin, P. T. Mather, F. E. Arnold, Jr., L.-S. Tan, "Propargyl-terminated Hyperbranched Poly(arylene-ether-ketone-imide) with Various Molecular Weights and Blends with an Ethynyl-terminated Bisimide Resin." *Polymer Preprints* 45(2), 651-652 (2004).

2005

K. L. Anderson, E. Manias, R. A. Vaia and B. L. Farmer. "Dispersion of single walled carbon nanotubes by sodium dodecyl sulfonate surfactants in aqueous solution: Molecular dynamics simulations". *PMSE Preprints*, 93, 375-376 (2005).

K. L. Anderson, E. Manias, R. A. Vaia and B. L. Farmer. "Deformation and failure of polymer - layered silicate nanocomposites: coarse grained computer simulations". *PMSE Preprints*, 92, 207-208 (2005).

Z. Bai, T. D. Dang, M. F. Durstock, S. J. Rodrigues, T. L. Reitz "Wholly Aromatic Sulfonated Polyarylenethioether Sulfone Copolymers as PEM for Fuel Cells" *Polymer Preprints* (American Chemical Society, Division of Polymer Chemistry), Vol. 46(1), p865, 2005.

J-Y. Choi, D. H. Wang, L.-S. Tan and J.-B. Baek. "Grafting of hyperbranched polyetherketones onto multi-walled carbon nanotubes via A3 + B2 approach". *Polymer Preprints*, 46(2), 753-754 (2005).

S. J. Clarson, A. V. Jadhav, S. Oztemiz, R. Kannan and L.-S. Tan. "New materials for two photon fabrication applications". *Polymer Preprints*, 46, 64-65 (2005).

T. D. Dang, S. Kumar, T. Uchida, K. L. Strong and N. Venkatasubramanian. "Alignment of SWNTs in lyotropic rigid-rod polymer compositions". *Polyimides and Other High Temperature Polymers Proceedings*, 3, 517-533 (2005).

Drummy, Lawrence F.; Koerner, Hilmar; Farmer, Karen; Tan, Ashley; Farmer, B. L.; Vaia, Richard A., High-Resolution Electron Microscopy of Montmorillonite and Montmorillonite/Epoxy Nanocomposites, *Journal of Physical Chemistry B* (2005), 109(38), 17868-17878.

Drummy, L. F.; Koerner, H.; Tan, A.; Farmer, K.; Farmer, B. L.; Vaia, R. A., "High Resolution Electron Microscopy of Layered Silicate/Epoxy Nanocomposites", *ACS Conference Proceedings*, PMSE-098, 92 165-166, 2005.

Farmer, B. L.; Anderson, K. L.; Vaia, R. A.; Manias, E., "Deformation and Failure of Polymer-Layered Silicate Nanocomposites: Coarse Grained Computer Simulations", *ACS Conference Proceedings*, PMSE-124, 92, 207-208, 2005.

Freund, M.; Vaia, R. A.; Brown, G.; Pomrenke, G., "NanoScience and Technology for the Air Force", *AF Tech Horizons*, 2005.

Heinz, Hendrik; Koerner, Hilmar; Anderson, Kelly L.; Vaia, Richard A.; Farmer, B. L., Force Field for Mica-Type Silicates and Dynamics of Octadecylammonium Chains Grafted to Montmorillonite, *Chemistry of Materials* (2005), 17(23), 5658-5669.

Heinz, H.; Vaia, R. A.; Farmer, B. L., "Self-Assembly of Alkylammonium Chains on Montmorillonite: Effect of Chain Length, Head Group Structure, and Cation Exchange Capacity", *ACS Conference Proceedings*, POLY-058, 46(2), 82-83, 2005.

Heinz, H.; Vaia, R. A.; Farmer, B. L., "Free Energy of Exfoliation Between Layered Silicate Sheets", *ACS Conference Proceedings*, PMSE-532, 93, 921-922, 2005.

Heinz, H.; Koerner, H.; Anderson, K. L.; Vaia, R. A.; Farmer, B. L., "Towards Quantitative Modeling of Surface Properties in Inorganic-Organic Hybrid Materials", *ACS Conference Proceedings*, PMSE-529, 93, 917-918, 2005.

Jakubiak, Rachel; Tondiglia, Vincent P.; Natarajan, Lalgudi V.; Sutherland, Richard L.; Lloyd, Pamela; Bunning, Timothy J.; Vaia, Richard A., Dynamic lasing from all-organic two-

dimensional photonic crystals, *Advanced Materials* (Weinheim, Germany) (2005), 17(23), 2807-2811.

Jakubiak, R.; Tondiglia, V. P.; Natarajan, L. V.; Sutherland, R. L.; Lloyd, P.; Bunning, T. J.; Vaia, R. A., "Stimulated Emission from Pyrromethene 597 in Holographic Polymer Dispersed Liquid Crystal Structures", *SPIE Conference Proceedings*, Vol. 5724, p. 202-207, Organic Photonic Materials and Devices VII; James G. Grote, Toshikuni Kaino, Francois Kajzar; Eds., April 2005.

Koerner, H.; Hampton, E.; Dean, D.; Turgut, Z.; Drummy, L.; Mirau, P.; Vaia, R. A., "Time-resolved Morphology Development of Tri-axial Reinforced Epoxy Montmorillonite Nanocomposites in Uni-axial Magnetic Fields", *Science Highlights*, NLSWeb site and Bulletin, August 17, 2005.

H.-J Lee, S.-J Oh, D.-K. Keum, L.-S. Tan and J.-B. Baek. "Functionalization of carbon nanotubes with substituted benzoic acids via Friedel-Crafts reaction in polyphosphoric acid". *Polymer Preprints*, 46, 199-200 (2005).

H.-J Lee, S.-J Oh, J.-Y. Choi, J. W. Kim, J. Han, L.-S. Tan and J.-B. Baek. "Polyethyleneterephthalate (PET) via in-situ polymerization of ethylene glycol containing functionalized carbon nanotube and terephthalic acid". *Polymer Preprints*, 46, 777-778 (2005).

Lyuksyutov, S. F.; Juhl, S. B.; Paramonov, P. B.; Vaia, R. A., "Atomic Force Microscopy Electrostatic Nanolithography (AFMEN): Manipulation of Thin Polymer Films Under Extreme Electrostatic Potentials", *ACS Conference Proceedings*, PMSE-140, 92, 237-238, 2005.

P. A. Mirau, R. A. Vaia and J. Garber. "NMR characterization of the structure and dynamics of polymer interfaces in clay nanocomposites". *Polymer Preprints*, 46, 440-441 (2005).
Mirau, P. A.; Vaia, R. A.; Garber, J., "NMR Characterization of the Structure and Dynamics of Polymer Interfaces in Clay Nanocomposites", *ACS Conference Proceedings*, POLY-149, 46(1), 440-441, 2005.

Natarajan, L. V.; Brown, D. P.; Tondiglia, V. P.; Sutherland, R. L.; Lloyd, P.; Jakubiak, R.; Vaia, R. A.; Bunning, T. J., "Photoinitiator System for Visible Wavelength Laser Writing of Thiol-ene H-PDLC Bragg Reflection Gratings", *ACS Conference Proceedings*, PMSE-367, 93, 617-618, 2005.

Natarajan, L. V.; Brown, D. P.; Wofford, J. M.; Tondiglia, V. P.; Sutherland, R. L.; Lloyd, P.; Jakubiak, R.; Vaia, R. A.; Bunning, T. J., "Visible Light Initiated Thiol-ene Based Reflection HPDLCs", *SPIE Conference Proceedings*, Vol. 5936, p. 60-67, Liquid Crystals IX, Iam-Choon Khoo; Ed., August 2005.

S.-J. Oh, H.-J. Lee, D.-K. Keum, S.-W. Lee, S.-Y. Park, L.-S. Tan and J.-B. Baek. "Polymerizations of 3- and 4-phenoxybenzoic acids onto carbon nanotubes via electrophilic substitution reaction in polyphosphoric acid". *Polymer Preprints*, 46, 216-217 (2005).

R. B. Pandey, K. L. Anderson, H. Heinz and B. L. Farmer. "Effects of temperature and solvent quality on the relaxation of a clay sheet: Monte carlo simulation". *PMSE Preprints*, 92, 291-292 (2005).

Pender, Mark J; Hartgerink, Jeffrey D.; Maruyama, Benji; Naik, Rajesh R.; Stone, Morley O.; Vaia, Richard A., Selectively derivatized single wall carbon nanotube networks via peptide-mediated, non-covalent modification *Polymer Preprints* (American Chemical Society, Division of Polymer Chemistry) (2005), 46(1), 83-84.

Radloff, C. J; Juhl, S. B.; Vaia, R. A.; Brunton, J; Ward, V.; Kalmakoff, J; Dokland, T.; Ha, Y-H; Thomas, E. L., "Bio-scaffolds for Ordered Nanostructures and Metallodielectric Nanoparticles", *SPIE Conference Proceedings*, Vol. 5592, p. 143-152, Nanofabrication: Technologies, Devices, and Applications; Warren Y. Lai, Stanley Pau, O. Daniel Lopez; Eds., January 2005.

Vaia, Richard; Mirau, Peter; Alexander, Max; Koerner, Hilmar; Hsiao, Benjamin S; Sics, Igors, Morphology-deformation correlations in nanocomposites, *Rubber World* (2005), 233(1), 43-45.

R. A. Vaia, H. Koerner, D. Powers, P. Mirau, M. Alexander and M. Arlen. "Polymer nanocomposites as adaptive materials: carbon nanotube-polyurethane stress recovery systems". *Polymer Preprints*, 46(2), 542-543 (2005).

Vaia, R. A., "Nanocomposites: Remote-Controlled Actuators", *Nature Materials*, 4(6), 429-430, 2005.

Vaia, Richard; Mirau, Peter; Alexander, Max; Koerner, Hilmar; Hsiao, Benjamin S; Sics, Igors, Morphology-deformation correlations in nanocomposite elastomers, Spring Technical Meeting - American Chemical Society, Rubber Division, 167th, San Antonio, TX, (2005), 63/1-63/8.

Vaia, R. A.; Koerner, H.; Powers, D.; Mirau, P. A.; Alexander, M. D.; Arlen, M., "Polymer Nanocomposites as Adaptive Materials: Carbon Nanotube - Polyurethane Stress Recovery Systems", *ACS Conference Proceedings*, POLY-526, 46(1), 542-543, 2005.

Vestal, C.R. "Fabrication and Frequency Dependent Properties of Polymer Nanocomposites Containing Magnetic Nanoparticles." *Nanocomposites 2005 Proceedings*, 2005.

D. H. Wang, J-B. Baek and L.-S. Tan. "Phthalonitrile-terminated hyperbranched poly(arylene-ether-ketone-imide): synthesis and its blending with 4,4'-bis(3,4-dicyanophenoxy)biphenyl". *Polymer Preprints*, 46, 727-728 (2005).

D. H. Wang, M. Houtz, J-B. Baek and L.-S. Tan. "In-situ polymerization of 6FDA and 1,3-bis(3-aminophenoxy)benzene in the presence of aminefunctionalized vapor-grown carbon nanofibers". *Polymer Preprints*, 46, 920-921 (2005).

2006

Arlen, Michael; Koerner, Hilmar; Taylor, Barney; Alexander, Max; Vaia, Richard., Anisotropy in the electrical properties of polyurethane elastomer / carbon nanofiber composites, *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)* (2006), 47(1), 476-477.

Sang-Wook Han, Se-Jin Oh, Loon-Seng Tan and Jong-Beom Baek. "Purification and functionalization of single-walled carbon nanotube (SWNT) in a mild polyphosphoric acid". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(2), 436-437 (2006).

Heinz, Hendrik; Vaia, R. A.; Farmer, B. L., Interaction energy and surface reconstruction between sheets of layered silicates. *Journal of Chemical Physics* (2006), 124(22), 224713/1-224713/9.

David Jacobs, Hilmar Koerner, Hendrik Heinz, Barry L. Farmer, Peter Mirau, Patrick H. Garrett, and Richard A. Vaia Dynamics of Alkyl Ammonium Intercalants within Organically Modified Montmorillonite: Dielectric Relaxation and Ionic Conductivity, *J Chem Phys. B* 110(41), 20143 – 20157, 2006

In-Yup Jeon, Soo-Young Park, Loon-Seng Tan and Jong-Beom Baek. "Grafting of linear and hyperbranched flexible polyetherketones onto the surface of multiwalled carbon nanotube". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(2), 389-390 (2006).

Rachel Jakubiak, Dean P. Brown, Lalgudi V. Natarajan, Vincent Tondiglia, Pamela Lloyd, Richard L. Sutherland, Timothy J Bunning and Richard A. Vaia., Influence of morphology on the lasing behavior of pyrromethene 597 in a holographic polymer dispersed liquid crystal reflection grating, *SPIE Proceedings from the 2006 Annual Meeting, San Diego, CA.* 2006 in press.

Shalin J Javeri, Christopher A. Coenjarts, Loon-Seng Tan, Matthew R. Hynd, Ramamurthi Kannan, Richard A. Vaia, James N. Turner, William Shain and Christopher K. Ober. "Two-photon three-dimensional patterning of gels and elastomers". *PMSE Preprints*, 94, 44-45 (2006).

Juhl, Shane B.; Chan, Edwin P.; Ha, Yung-Hoon; Maldovan, Martin; Brunton, Jason; Ward, Vernon; Dokland, Terje; Kalmakoff, James; Farmer, Barry; Thomas, Edwin L.; Vaia, Richard A., Assembly of Wiscana iridovirus: viruses for colloidal photonic crystals. *Advanced Functional Materials* (2006), 16(8), 1086-1094.

Koerner, Hilmar; Misra, Devesh; Tan, Ashley; Drummy, Lawrence; Mirau, Peter; Vaia, Richard, Montmorillonite-thermoset nanocomposites via cryo-compounding. *Polymer* (2006), 47(10), 3426-3435.

Lee, Se-Jin Oh, Ja-Young Choi, Loon-Seng Tan and Beom Baek. "Functionalization of multi-wall carbon nanotube as functions of reacting groups and substituents". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(1), 394-395 (2006).

Hwa-Jong Lee, Ja-Young Choi, Dong-Hwan Cho, Do Kim, Loon-Seng Tan and Jong-Beom Baek. "Multi-wall carbon nanotubes/thermoplastic polyester elastomers nanocomposites". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(2), 400-401 (2006).

Lu, W., Koerner, H., Vaia, R., "Effect of Electric Field on Exfoliation of Nanoplates" *Appl. Phys. Letters*, 89, 223118, 2006.

Lyuksyutov, S. F.; Paramonov, P. B.; Mayevska, O. V.; Reagan, M. A.; Sancaktar, E.; Vaia, R. A.; Juhl, S., Atomic force microscope tip spontaneous retraction from dielectric surfaces under applied electrostatic potential, *Ultramicroscopy* (2006), 106(10), 909-913.

Paramonov, Pavel B.; Lyuksyutov, Sergei F.; Mayevska, Olga V.; Reagan, Michael A.; Umemura, Kazuo; Tobar, Hiroaki; Hara, Masahiko; Vaia, Richard A.; Juhl, Shane, Rearrangements in an Alkylthiolate Self-Assembled Monolayer Using Electrostatic Interactions between Nanoscale Asperity and Organomeraptan Molecules. *Langmuir* (2006), 22(15), 6555-6561.

Laura Sennet, Loon-Seng Tan and Eric Fossum. "Synthesis of branched poly(ether ketone) copolymers via reactions of AB and AB_n monomers in the presence of core molecules". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(1), 327-328 (2006).

David H. Wang and Loon-Seng Tan. "Synthesis and characterization of acetylene-terminated hyperbranched poly(arylene-ether-ketone-imide)s". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(1), 298-299 (2006).

David H. Wang, Jong-Beom Baek, Shirley F. Nishino, Jim C. Spain and Loon-Seng Tan. "Semi-enzymatically produced 6-phenylethynyl picolinic acid as endcapping agent: synthesis and thermal properties of phenylethynyl-terminated bis(benzylester) and bis(amide) monomers". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(1), 266-267 (2006).

David H. Wang, Timothy Marsh, Patrick T. Mather and Loon-Seng Tan. "Improved monomer synthesis for poly(arylene-ether-ketone-imide)". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(2), 530-531 (2006).

David H. Wang, Jong-Beom Baek and Loon-Seng Tan. "Grafting of a hyperbranched poly(ether-ketone) onto multi-walled carbon nanotubes with an AB₂ monomer". *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)*, 47(2), 387-388 (2006).

Xu, Yijin; Brittain, William J; Vaia, Richard A.; Price, Gary, Improving the physical properties of PEA/PMMA blends by the uniform dispersion of clay platelets. *Polymer* (2006), 47(13), 4564-4570.

2007

Drummy, L, Koerner, H., Farmer, B., Vaia, R., "Advanced Morphology Characterization of Clay-based Polymer Nanocomposites", CMSWorkshop Lectures, Vol. 15, Kathleen A. Carrado and Faiza Bergaya eds., *The Clay Minerals Society*, Chantilly, VA, 99-142 (2007).

Engel, J, Shaikh, K., Arlen, M., Chen, N., Pandya, S, Tucker, C., Yang, Y., Vaia, R., Liu, C., "Nano-Composite Elastomer and Multilayer Soft Lithography Technology for Soft MEMS" *J of MEMS* 2007, in press.

B.F. Farmer, R.A.Vaia, Molecular Dynamics Simulations of Hybrid Polymers and Nanocomposites in Organic-Inorganic Hybrid Materials, ECS Publ. in press

Hendrik Heinz, R. A. Vaia, R. Krishnamoorti, B. L. Farmer Self-Assembly of Alkylammonium Chains on Montmorillonite: Effect of Chain Length, Head Group Structure, and Cation Exchange Capacity Chemistry of Materials, 2007, 19(1); 59-68.

Voevodin, A., Vaia, R., Patton, S., Diamanti, S., Pender, M., Yoonsesi, M., Brubaker, J, Hu, J, Sanders, J, Phillips, B., MacCuspie, R., "Nanoparticle-Wetted Surfaces for Relays and Energy Transmission Contacts", *Small*, 2007, in press.

Wang, D., Arlen, M., Baek, J, Vaia, R., Tan, L-S, "Nanocomposites Derived from a Low-Color Aromatic Polyimide (CP2) and Maleic-Functionalized Vapor-Grown Carbon Nanofibers: In-Situ Polymerization and Characterization", *Macromolecules* 2007, in press. Natarajan, L., Wofford, J, Tondiglia, V., Sutherland, R., Svec, S, Koerner, H., Vaia, R., Bunning, T., "Tuning of a Cholesteric Filter Having a Negative Dielectric Anisotropy", *Symposium on 'Liquid Crystals'*, Aug.26-30, 2007, San Diego, SPIE Proceedings, Vol.6654 (in Press).

Zheng, X., Forest, M., Vaia, R., Arlen, M., Zhou, R., "A Strategy for Dimensional Percolation in Sheared Nano-rod Dispersions" *Adv. Mater.* 2007, in press.

R.A.Vaia, B.F. Farmer, T. Bunning, MesoStructure Control in Polymer-Inorganic Nanocomposites in Organic-Inorganic Hybrid Materials, ECS Publ. in press

R. Vaia, J Maguire, Polymer Nanocomposites with Prescribed Morphology: Going Beyond NanoParticle-Filled Polymers (review), Chem. Material, 2007 19(11); 2736-2751.

Vaia, R.A., Winey, K. eds. Polymer Nanocomposites, *MRS Bulletin*, vol 32 (4), MRS, Pittsburgh PA 2007.

Junbing Yang, Liangti Qu, Ye Zhao, QiuHong Zhang, Liming Dai, Jeffery W. Baur, Benji Maruyama, Rich A. Vaia, Eunsung Shin, P. Terrence Murray, Hongxia Luo, Zhi-Xin Guo, Multicomponent and Multidimensional Carbon Nanotube Micropatterns by Dry Contact Transfer Journal of Nanoscience and Nanotechnology Vol.7, 1– 8, 2007.

5.2 Publications (Books, Articles, Other):

Vaia, R. A.; Tolle, T. B; Schmitt, G. F.; Imeson, D.; Jones, R. J Nanoscience and nanotechnology: materials revolution for the 21st century. *SAMPE Journal* (2001), 37(6), 24-31.

R. Vaia, Polymer Nanocomposites, *AFRL Technology Horizons*, 3(3), 2002, 41-42

Nanophase and Nanocomposite Materials IV. (Proceedings of the Symposium held 26-29 November 2001 in Boston, Massachusetts.) [In: *Mater. Res. Soc. Symp. Proc.*, 2002; 703]. Komarneni, Sridhar; Parker, John C.; Vaia, Richard A.; Lu, G. Q.; Matsushita, Jun-ichi; Editors. USA. (2002), 592 pp. Publisher: (Materials Research Society, Warrendale, Pa

Vaia, R A.; Krishnamoorti, R Polymer nanocomposites: introduction. *ACS Symposium Series* (2002), 804(Polymer Nanocomposites), 1-5

Polymer Nanocomposites: Synthesis, Characterization, and Modeling. [In: *ACS Symp. Ser.*, 2002; 804]. Krishnamoorti, Ramanan; Vaia, Richard A.. USA. (2002), 242 pp. Publisher: (American Chemical Society, Washington, D. C.)

Vaia, R. A. Polymer nanocomposites open a new dimension for plastics and composites *AMPTIAC Newsletter* (2002), 6(1), 17-24

Kannan, R.; Tan, L-S; Vaia, R.A. Two-photon responsive chromophores containing electron accepting U.S (2003), 6 pp. CODEN: USXXAM US 6555682 B1 20030429 Patent written in English. Application: US 2002-171567 20020613. CAN 138:339708 AN 2003:330960

"Composite Materials", R.A. Vaia interview, *ACS C&EN Coverstory*, Volume 82, Number 35, pp. 34-39, August 30, 2004.

Kannan, Ramamurthi; Tan, Loon-seng; Reinhardt, Bruce A.; Vaia, Richard A. Two-photon responsive chromophores containing electron accepting core units U.S. (2004), 6 pp. Application: US 2002-171566 20020613. CAN 140:392334 AN 2004:360279 US6730793,B120040504,US2002-171566,20020613

Alexander, Max, Wang, C-S, et al. Method of forming conductive polymeric nanocomposite materials USPATENT #6,680,016 January 20, 2004

Miziolek, A. W.; Karna, S. P.; Mauro, J. M.; Vaia, R. A., "Defense Applications of Nanomaterials", *ACS Symp. Ser.*; 891, 346, 2005.

Mirau, P. A.; Vaia, R. A., "Solid-State NMR Characterization of Polymer Interfaces", An invited review for "*Handbook of Magnetic Resonance*", Kluwer Academic Publisher, 2005, in press.

"NanoFillers Lead Polymer in Functional Composites", R.A. Vaia interview, *High Performance Composites*, 30-36, September 2005.

Del Sesto, Rico E.; Dudis, Doug S.; Ghebremichael Fasil; Heimer, Norman E.; Low Tammy K. C.; Wilkes, John S.; Yeates, A. Todd, "Nonlinear optical ionic liquids," ACS Symposium Series, 902(Ionic Liquids IIIB: Fundamentals, Progress, Challenges and Opportunities), 144-158(2005).

Dudis, Douglas S.; Yeates, Alan T.; Das, Guru P.; Blaudreau, Jean P., "Quantum approaches for nanoscopic materials and phenomena," ACS Symposium Series, 891(Defense Applications of Nanomaterials), 278-292(2005).

R.A. Vaia interview, "Beyond Self-Tying Sutures", Technology Review (MIT), Monday, March 20, 2006 issue

M. H. C. Jn, M. F. Durstock, L. Dai "Optical Limiters and Photovoltaic Devices Based on C60, Carbon Nanotubes and their Nanocomposites", submitted, chapter in book entitled *Carbon Nanotechnology*.

S. Karna, M. Mauro, A. Miziolek, R. Vaia, eds Defense Applications of NanoMaterials, ACS Publishers, Washington DC. in press

S. Karna, M. Mauro, A. Miziolek, R. Vaia, eds Defense Applications of NanoMaterials, ACS Publishers, Washington DC. in press

Silicification and Biosilicification, Part 2, Silicification at pH 7 in the presence of a cationically charged polymer in solution and immobilized on substrates, Siddharth V.

Patwardhan, Michael F. Durstock, Stephen J. Clarson, in 'Synthesis and Properties of Silicones and Silicone-Modified Materials', (Eds. S. J. Clarson, J. J. Fitzgerald, M. J. Owen, S. D. Smith and M. E. Van Dyke), Book chapter, ACS Symposium Series Vol 838 / Oxford University Press, 2003, ISBN 0-8412-3804-9.

Douglas S. Dudis, Alan T. Yeates, Guru P. Das and Jean P. Blaudeau, "Quantum Approaches for Nanoscopic Materials and Phenomena," invited book chapter, American Chemical Society, *in press*.

Rico E. Del Sesto, Doug S. Dudis, Fasil Ghebremichael, Norman E. Heimer, Tammy K. C. Low, John S. Wilkes, A. Todd Yeates, "Nonlinear Optical Ionic Liquids," chapter in American Chemical Society Symposium Series, *submitted*.

5.3 Invention Disclosures and Patents:

T. Dang, M. F. Durstock, Z. Bai, M. J. Dalton "Sulfonated Polyarylenethioethersulfone Polymer Compositions", U.S. Patent Application Serial No. 11/005,248 filed December 6, 2004.

Arlen, M., Tan, L-S., Wang, Y., Vaia, R., "Nanocomposites and Functionalized Carbon Nanotubes", U.S. Patent Application Serial No. 11/494,041. Filed 8/27/2006

Lyuksyutov, S., Juhl, S., Vaia, R., Paramonov, P., "Method of Amplitude Modulated Electrostatic Polymer Nanolithography", U.S. Patent 7,241,992,

Lyuksyutov, S., Juhl, S., Vaia, R., Paramonov, P., "Method of Amplitude Modulated Electrostatic Polymer Nanolithography", U.S. Patent 7,241,992,

Patton, S., Sanders, J., Voevodin, A., Pender, M., Vaia, R., MacCuspie, R., Diamanti, S., "Nanoparticles and Corona Enhanced MEMS Switch Method", submitted 2007.

Patton, S., Sanders, J., Voevodin, A., Pender, M., Vaia, R., MacCuspie, R., Diamanti, S., "Nanoparticles and Corona Enhanced MEMS Switch Apparatus" submitted 2007.

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACRONYM	DESCRIPTION
AOARD	Asian Office of Aerospace Research and Development
CNF	Carbon Nanofiber
ABA	A polymer with similar ends and a different middle
AFOSR-DURINT	Air Force Office of Scientific Research-Defense University Research Initiative and Nano Technology
NMP	N-Methyl-2-pyrrolidone (a chemical compound)
AFX	Air Force Nonlinear Optical Chromophore
PAEKI	Chain-end-functinalized hyperbranched polymers
VGCNF	Vapor Grown Carbon Nano Fibers
CCD	Charge Coupled Detector
MWNT	Multi Walled Nano Tubes
SWNT	Single Walled Nano Tubes
PNM	Polymer Nanostructured Materials
PNC	Polymer Nanocomposites
NMR	Nuclear Magnetic Resonance
PBG	Photonic Band-gap
CIA	Central Intelligence Agency
ONR	Office of Naval Research
UCSB	University of California-Santa Barbara
ASEE	American Society for Engineering Education
CINT	Center for Intergrated Technologies
NIST	National Institute of Standards and Technology
RF MEM	Radio Frequency Microelectromechanical Systems
SOA	State of the Art
TPA	Two-photon Resonant